QH1
A4
ser.3
v.23
Jan.-June
1882

THE

AMERICAN JOURNAL OF SCIENCE.

EDITORS

JAMES D. AND E. S. DANA, AND B. SILLIMAN.

ASSOCIATE EDITORS

PROFESSORS ASA GRAY, JOSIAH P. COOKE, AND JOHN TROWBRIDGE, OF CAMBRIDGE,

PROFESSORS H. A. NEWTON AND A. E. VERRILL, OF NEW HAVEN,

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA.

THIRD SERIES.

VOL. XXIII.—[WHOLE NUMBER, CXXIII.]

Nos. 133—138.

JANUARY TO JUNE, 1882.

WITH FOUR PLATES.

NEW HAVEN, CONN.: J. D. & E. S. DANA.
1882.

MISSOURI BOTANICAL
GARDEN LIBRARY

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS,

NEW HAVEN, CONN.

CONTENTS OF VOLUME XXIII.

NUMBER CXXXIII.

Page

ART. I.—Contributions to Meteorology: Mean annual Rainfall for different countries of the globe; by ELIAS LOOMIS. With Plate I (Map), ... 1

II.—Post-Glacial joints; by G. K. GILBERT, ... 25

III.—Sound-Shadows in water; by JOHN LECONTE, ... 27

IV.—The Connection between the Cretaceous and the recent Echinid Faunæ; by A. AGASSIZ, ... 40

V.—Apparatus for determining without pain to the patient the position of a projectile of lead or other metal in the human body; by A. G. BELL, ... 46

VI.—Observations of the transit of Mercury, 1881, November 7, at Mount Hamilton, California; by E. S. HOLDEN and S. W. BURNHAM, ... 48

VII.—Classification of the Dinosauria; by O. C. MARSH, ... 81

SCIENTIFIC INTELLIGENCE.

Physics and Chemistry.—Lunar Disturbance of Gravity, G. H. DARWIN and H. DARWIN, 49.—Drops floating on the surface of water: Photometric investigation of the absorption of light, 50.—Density of the Earth, JOLLY: New arrangement for sensitive flames, RAYLEIGH: Effect of vibrations upon a suspended disc, RAYLEIGH, 51.—Edison's Electrical Meters, 52.—Carbonic acid in Seawater, H. TORNÖE, 53.—Action of the oxides of Nitrogen on glass at a high temperature, T. M. MORGAN, 55.

Geology and Mineralogy.—Periodical variations of Glaciers, F. A. FOREL, 56.—Movement of Glaciers: Soilcap-Motion, R. W. COPPINGER, 59.—Evaporation and eccentricity as co-factors in Glacial periods, E. HILL, 61.—Geological and Natural History Survey of Minnesota for 1880, N. H. WINCHELL, 62.—Joints or diaclases intersecting the stratified rocks in the vicinity of Paris, M. DAUBRÉE, 63.—Brick-clays making cream-colored bricks in Minnesota, N. H. WINCHELL: Geology of Frenchman's Bay, Maine, W. O. CROSBY: Coking coal and anthracite of Colorado, J. S. NEWBERRY, 64.—Copper-bearing region in Northern Texas and the Indian Territory, J. H. FURMAN: The Amygdaloid of Brighton, Mass.: Primordial Trilobites in Sardinia: Journal of the Cincinnati Society of Natural History: Fossils of the Cincinnati Rocks: Volcanoes, what they are and what they teach, J. W. JUDD, 65.—Mineralogical Notes, E. CLAASSEN, 67.—Analysis of the Emerald-green Spodumene from North Carolina, F. A. GENTH: New Mineralogical Works, G. TSCHERMAK, 68.

Botany and Zoology.—Manual of the Coniferæ, 69.—Repertorium Annuum Literaturæ Botanicæ Periodicæ, G. C. W. BOHNENZIEG: Jahrbuch des Königlichen Botanischen Gartens und des Botanischen Museum zu Berlin, A. W. EICHLER, 70.—ENGLER'S Botanische Jahrbücher für Systematik: HOOKER'S Icones Plantarum: Additional specimen of Architeuthis at Newfoundland, A. E. VERRILL, 71.—Some new and rare Cephalopoda, R. OWEN, 72.—Zoology of H. M. S. Challenger, A. AGASSIZ, 75.—Geographical Distribution of certain freshwater Mollusks of North America, A. G. WETHERBY, 76.

Astronomy.—Elements of Comet VII, Boss: Longitude of Morrison Observatory, Glasgow, Mo., J. R. EASTMAN and H. S. PRITCHETT, 76.

Miscellaneous Scientific Intelligence.—Annual Report of the Chief Signal Officer of the Army to the Secretary of the War for the year 1881, 78.—National Academy of Science, Nov., 1881, 79.—*Obituary.*—Mr. Robert Mallet, F.R.S., 80.

NUMBER CXXXIV.

Page

ART. VIII.—The Flood of the Connecticut River Valley from the melting of the Quaternary Glacier; by J. D. DANA, 87
IX.—Geology of the Diamond; by O. A. DERBY, 97
X.—Algebraic Expression of the Diurnal Variation of Temperature; by B. A. GOULD, 99
XI.—Celestial Chemistry from the Time of Newton; by T. STERRY HUNT, 123
XII.—A Cercaria with Caudal Setæ; by J. W. FEWKES, 134
XIII.—Notice of the remarkable Marine Fauna occupying the outer banks off the Southern coast of New England, No. 3; by A. E. VERRILL, 135

SCIENTIFIC INTELLIGENCE.

Physics and Chemistry.—Vapor-density of the Halogens, VICTOR MEYER: Air-thermometer convenient for Chemical purposes, ANDREWS, 143.—On the existence of Phosphorus oxide, REINITZER: Preparation of spontaneously inflammable Hydrogen phosphide, BRÖSSLER, 144.—Ammonium tribromide, ROOZEBOOM: Petroleum of the Caucasus, BEILSTEIN and KURBATOW, 145.—On the reactions of Chinoline, DONATH: On the theory of the Peptones, POEHL, 146.—On the existence of Allantoin in Vegetables, SCHULZE and BARBIERI: Observations upon Klangfarbe: W. Siemens upon the Dynamo-Electric Machine, 147.—Theory of the rotation of the plane of Polarization of Light, 148.—Electrical Resistance of a Vacuum, EDLUND: Elementary Treatise on Electricity, J. CLERK-MAXWELL, 149.—Tables of Qualitative Analysis, H. G. MADAN, 150.

Geology and Mineralogy.—International Geological Congress at Bologna, 150.—Notice of the discovery of a Pœcilopod in the Utica slate formation, 151.—Coal-Field near Cañon City, Colorado, J. J. STEVENSON: The Palæolithic Implements of the Valley of the Delaware, 152.—Bryozoans of the Upper Helderberg Group, JAMES HALL: Tertiary of the Eastern and Southern United States, ANGELO HEILPRIN: Cambarus primævus, a Crayfish, from the Lower Tertiary beds of Western Wyoming, A. S. PACKARD: American Museum of Natural History, WHITFIELD, 153.—Petroleum in the Northwest Territories of British America: Traité de Géologie par A. de Lapparent: Jelly-like Hydrocarbon from Scranton, Pennsylvania, 154.—Brief notices of some recently described minerals: Artificial Enstatite and Chrysolite, 155.—Supposed Organic Remains in Meteorites, 156.—Tabellarische Uebersicht der Mineralien nach ihren krystallographisch-chemischen Beziehungen geordnet von PAUL GROTH, 157.

Botany and Zoology.—Natural History Nomenclature, 157.—Maximowicz, de Coriaria, Ilice et Monochasma: Ueber sogenannte Compasspflanzen, E. STAHL, 159.—The Brain of the Cat, B. G. WILDER, 160.

Astronomy.—Notation of Comets: Astronomische Nachrichten, begründet von H. C. Schumacher: Washington Observations for 1877—Appendix III, 160.—Thirty-sixth Annual Report of the Director of the Astronomical Observatory of Harvard College, E. C. PICKERING, 161.—Beebe's Four-Place Tables, 162.

Miscellaneous Scientific Intelligence.—Mining Industries, A. D. HAGUE: Were Ancient Copper implements hammered or moulded into shape, F. W. PUTNAM, 162.—*Obituary.*—JOHN WILLIAM DRAPER, 163.—LEWIS H. MORGAN, 166.

NUMBER CXXXV.

Page

ART. XIV.—Color Correction of double Objectives; by C. S. HASTINGS, ... 167
XV.—To Cut a Millimeter Screw; by C. K. WEAD, ... 176
XVI.—Gold-bearing Rocks of the Province of Minas Geraes, Brazil; by O. A. DERBY, ... 178
XVII.—The Flood of the Connecticut River Valley from the melting of the Quaternary Glacier; by J. D. DANA. With Plate II, ... 179
XVIII.—Geographical Distribution of certain Fresh-water Mollusks of North America, and the probable causes of their Variation; by A. G. WETHERBY, ... 203
XIX.—Description of a New Genus of the Order Eurypterida from the Utica Slate; by C. D. WALCOTT, ... 213
XX.—Notice of the remarkable Marine Fauna occupying the outer banks off the Southern coast of New England, No. 4; by A. E. VERRILL, ... 216
XXI.—A new form of Reversible Stereoscope; by W. L. STEVENS, ... 226
XXII.—Magnetic Properties of a Specimen of Nickeliferous Iron from St. Catarina, Brazil, with a note by J. Lawrence Smith; by H. BECQUEREL, ... 229
XXIII.—Origin of Jointed Structure in undisturbed Clay and Marl deposits; by J. LECONTE, ... 233

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics.—Relation between the Optical and Thermal phenomena of Liquid Organic substances, BRÜHL, 234.—Simple Dissociation Apparatus, TOMMASI, 235.—Effect of Oxides on the Decomposition of Potassium Chlorate, MILLS and DONALD: Freezing point of Sulphuric acid of different degrees of concentration, LUNGE. 236.—Action of Water on Bismuthous iodide as illustrating Chemical change, P. MUIR: Splitting of Petroleum hydrocarbons at low Temperatures, GUSTAVSON, 237.—Occurrence of Metaisocymene in Rosin oil, KELBE: Aldehyde-nature of living Protoplasm, LOEW and BOKORNY, 238.—Viscosity of Gases at high exhaustions, 239.—Contributions to the Theory of Electro-magnetism: Disintegration of Electrodes by Positive Electricity, REITLINGER and WÄCHTER: Upper limit for the Kinetic Energy of moved Electricity, MAXWELL, 240.—Electrical Units recommended by the Electrical Congress of 1881: Lessons in Electricity and Magnetism, S. P. THOMPSON, 241.

Geology.—Glacial Erosion in Maine, G. H. STONE: Glacial phenomena on the Delaware, G. F. WRIGHT, 242.—Jura-Trias in Colorado, R. C. HILLS, 243.

Botany and Zoology.—Notes on Gramineæ, G. BENTHAM: Flora Brasiliensis, 244.—Diagnoses Plantarum novarum Asiaticarum, C. J. MAXIMOWICZ: Power possessed by Leaves of placing themselves at right-angles to the direction of Incident Light, F. DARWIN. 245.—The Botanical Collector's Handbook, W. W. BAILEY, 246.—The Greenland Flora: A Memoir on the Echinodermata of the Arctic Sea, P. M. DUNCAN and W. P. SLADEN, 247.—Discovery of a rare fresh-water shell (Gundlachia) in western New York. J. M. COOKE, 248.

Miscellaneous Scientific Intelligence.—Minor Planets: Hailstorms, J. A. B. OLIVER, 249.—Schott's Tables and Results of the Precipitation in Rain and Snow in the United States: Boston City Water, I. REMSEN: The Lalande Astronomical Prize: La Lumière Éllectrique: Cosmos-Les-Mondes, 250.

NUMBER CXXXVI.

Page

ART. XXIV.—The Wings of Pterodactyles; (with Plate III); by O. C. MARSH, ... 251

XXV.—Sandstones having the grains in part Quartz Crystals; by A. A. YOUNG, ... 257

XXVI.—Notes on American Earthquakes, No. 11; by C. G. ROCKWOOD, ... 257

XXVII.—Notes on the Electromagnetic Theory of Light, No. I; by J. W. GIBBS, ... 262

XXVIII.—The "Timber Line;" by H. GANNETT, ... 275

XXIX.—Simple Method for Calibrating Thermometers; by S. W. HOLMAN, ... 278

XXX.—Notice of Fisher's Physics of the Earth's Crust; by C. E. DUTTON, ... 283

XXXI.—Physiological Optics, No. III; by W. L. STEVENS, 290

XXXII.—Great dyke of Foyaite or Elæolite-syenite in Northwestern New Jersey; by B. K. EMERSON, ... 302

XXXIII.—Notice of the remarkable Marine Fauna occupying the outer banks off the Southern Coast of New England, No. 51; by A. E. VERRILL, ... 309

XXXIV.—Determination of Phosphorus in Iron; by J. L. SMITH, ... 316

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics.—Apparatus for illustrating the action of Geysers, 320.—Electrical resistance of Gases, E. EDLUND: Dielectric polarization in Electrolytes: Change of temperature due to extension and contraction of metallic wires, 321.—Phosphorescence, ABNEY: Discussion of the Fourier-Poisson theory of the conduction of heat: Spectroscopic observations with monochromatic light, M. ZENGER, 322.—Crystals of Potassium Chloride found in the extract of Wormwood or Absinth, E. CLAASSEN, 323.

Geology and Mineralogy.—Tides in early Geological time, 323.—Contributions to the History of the Vertebrata for the Lower Eocene of Wyoming and New Mexico, made during 1881, E. D. COPE, 324.—Report of the State Geologist of New Jersey, G. H. COOK: Dioptase from Arizona, R. C. HILLS: Analysis of a variety of Siderite, E. CLAASSEN, 325.

Botany and Zoology.—The Names of Herbes, W. TURNER: A Synopsis of the North American Lichens, E. TUCKERMAN, 326.—Botanische Mikrochemie, V. A. POULSEN: Nature and functions of the "Yellow Cells" of Radiolarians and Cœlenterates, 328.—Ueber das Zusammenleben von Thieren und Algen, 329.—*Botanical Necrology:* Thomas Potts James, etc., 330.—History and Present Condition of the Fishing Industries, S. F. BAIRD, 334.

Astronomy.—Micrometrical Measurements of 455 Double Stars, 1879-80: Names of small Planets, 334.—Photograph of the Spectrum of the Great Nebula in Orion, W. HUGGINS, 335.—Linear Associative Algebra, B. PEIRCE, 336.

Miscellaneous Scientific Intelligence.—Voyage of the Vega round Asia and Europe, with a historical review of previous journeys along the North Coast of the Old World, A. E. NORDENSKIÖLD: Guides for Science Teaching: Potassium permanganate, J. B. DELACERDA: Index to the Reports of the Chief of Engineers and the officers of the Corps of Engineers, 336.—Earthquake of March 4, 1881, in Ischia: The Swiss Seismological Commission, 337.—Glacier scratches in the Catskills: A. Geikie, Director of the Geological Survey of Great Britain, 338.—*Obituary.*—Sir C. Wyville Thomson, 338.

NUMBER CXXXVII.

Page

ART. XXXV.—Photographs of the Spectrum of the Nebula in Orion; by H. DRAPER, ... 339
XXXVI.—Mean Annual Rain-fall for different Countries of the Globe; by A. WOEIKOF, ... 341
XXXVII.—Physiological Optics, No. IV; by W. L. STEVENS, 346
XXXVIII.—Flood of the Connecticut River Valley from the Quarternary Glacier; by J. D. DANA, ... 360
XXXIX.—Brazilian specimens of Martite; by O. A. DERBY, 373
XL.—Method for determining the flexure of a Telescopic Tube for all positions of the Instrument; by J. M. SCHAEBERLE, 374
XLI.—Dykes of Micaceous Diabase penetrating the bed of Zinc Ore at Franklin Furnace; by B. K. EMERSON, ... 376
XLII.—Occurrence of Smaltite in Colorado; by M. W. ILES, 380
XLIII.—Vanadium in the Leadville Ores; by M. W. ILES, 381
XLIV.—Conditions attending the Geological Descent of some Fresh-water gill-bearing Mollusks; by C. A. WHITE, .. 382
XLV.—Measures of the Rings of Saturn in the years 1879, 1880, 1881 and 1882; by E. S. HOLDEN, ... 387
XLVI.—Interference Phenomena in a new form of Refractometer; by A. A. MICHELSON, ... 395
XLVII.—New Minerals, Monetite and Monite, with a notice of Pyroclasite; by C. U. SHEPARD, ... 400
XLVIII.—Marine Fauna off New England; by A. E. VERRILL, 406

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics.—Determination of Gas-densities, GOLDSCHMIDT and V. MEYER: Diffusion of Solids into Solids, COLSON, 409.—Production of Active Oxygen, TRAUBE: So-called Persulphuric oxide of Berthelot, MENDELEJEFF, 410.—Production and properties of metallic Cæsium, SETTERBERG, 411.—Metals of the rarer Earths, BRAVNER: Preparation of Cymene from Turpentine, NAUDIN: New Alkaloid from Cinchona Bark, HOWARD and HODGKIN, 412.—Coloring matter of the Chinese yellow berries, FOERSTER: Maximum of magnetization of diamagnetic and weakly paramagnetic bodies: Reflection of electrical rays, 413.—Influence of mechanical hardening upon the magnetic properties of steel and iron: Storage of Electricity, 414.—Storage of Electricity: Velocity of Sound in Wood, H. KAYSER, 415.—The Chemistry of Cooking and Cleaning, a manual for Housekeepers, E. H. RICHARDS, 416.

Geology and Natural History.—Bulletin of the Illinois Museum of Natural History: Glacial-era Climate, WOEIKOF, 417.—Post-Glacial Flood: Quincy Syenite, M. E. WADSWORTH: An old chapter of the Geological Record, W. KING and T. H. ROWNEY: Species of Eurypterus and Pterygotus from Buffalo: Chautauqua Scientific Diagrams, A. S. PACKARD, JR.: Tables for the Determination, etc., of Minerals, J. C. FOYE: Female Flowers of Coniferæ, EICHLER, 418.—Domestication of Wild Ducks, 421.—Conchologische Mittheilungen, E. VON MARTIUS, 422

Miscellaneous Scientific Intelligence.—First Annual Report of the Bureau of Ethnology, 422.—*Obituary.*—Charles Robert Darwin: E. Desor, 422.

NUMBER CXXXVIII.

Page

ART. XLIX.—Respiration of Plants; by W. P. WILSON,... 423
L.—On the Question of Electrification by Evaporation; by S. H. FREEMAN, ... 428
LI.—Observations on Snow and Ice under pressure at temperatures below 32° F.; by E. HUNGERFORD, ... 434
LII.—On the minerals, mainly Zeolites, occurring in the basalt of Table Mountain, near Golden, Colorado; by W. CROSS and W. F. HILLEBRAND, ... 452
LIII.—On a new Locality for Hayesine; by N. H. DARTON, 458
LIV.—Notes on the Electromagnetic Theory of Light, II; by J. W. GIBBS, ... 460
LV.—New Phyllopod Crustaceans from the Devonian of New York; by J. M. CLARKE. (With a Plate), ... 476
LVI.—An Organ-Pipe Sonometer; by W. LECONTE STEVENS, 479

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics.—New apparatus for determining melting points, CROSS and BEVAN, 482.—Critical Temperatures of Organic Liquids, PAWLEWSKI: New Carbon Sulphobromide, HELL and URECH, 483.—New Sulphur oxychloride, OGIER: Physical Properties of Carbon Oxysulphide, ILOSVAY, 484.—Formation of Metallic Alloys by Pressure, SPRING: Symmetrical Chlor-ethyl oxide, HANRIOT, 485.—Constitution of Quinones, JAPP and STREATFEILD: Preparation of Alizarin-orange, SIMON: Photometric Investigation, E. KETELER and C. PULFRICH, 486.—Theory of Elliptical double Refraction, E. LOMMEL: Difference of Potential between a Metal and Fluids of different concentration, E. KITTLER: Electrical Resistance of a Vacuum, E. EDLUND: Solar Heat, M. A. CROVA, 487.—Aconitic acid, from Sorghum Juices, H. B. PARSONS, 488.

Geology and Natural History.—The Climatic Changes of later Geological Times, J. D. WHITNEY, 489.—Third Appendix to the Fifth Edition of Dana's System of Mineralogy, E. S. DANA: The Genus Monticulipora, S. A. MILLER: Handbook of Invertebrate Zoology for Laboratories and Seaside Work, W. K. BROOKS: Absorption of metallic oxides by Plants, F. C. PHILLIPS, 491.—Monographie des Composées, H. BAILLON: Guide to the Flora of Washington and vicinity, L. F. WARD, 492.—Les Meilleurs Blés, etc., VILMORIN-ANDRIEUX: Resinous Matters in Plants, DE VRIES, 494.—A Popular Californian Flora, V. RATTAN, 495.

Miscellaneous Scientific Intelligence.—Astronomical Observations for 1877 at the U. S. N. Observatory: American Association, 495.—Norton's Astronomy, 496.—*Obituary.*—Sir Charles Wyville Thomson, 496.—General John G. Barnard: Charles M. Wheatley: William S. Vaux, 498.

ERRATA.

Page 29, line 18 for, at the disk, read, at the circumference of the disk.
Page 30, for J. I. LeConte read J. J. LeConte.
Page 35, 2d line from bottom, for remitting read remaining.
Page 37, 3d line of continued note, for different read distant.
Page 248, line 40, for John M. Cooke, read John M. Clarke.

Page 281, the expression in line 15 from top should read: $u' + u'' - \frac{2}{n}(B - A)$.

Page 349, the words *left* and *right* in lines 15 and 17 respectively should be exchanged.

Page 399, the expression above Eq. 7 should read: $= \frac{2t}{\lambda}(n_0 \tan i - \tan r) \sin i$.

Page 400, the expression after *or*, should read: $n_0 \cos i - n \cos r$.

THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. I.—*Contributions to Meteorology: being results derived from an examination of the Observations of the United States Signal Service and from other sources*; by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Sixteenth paper. With a map.

[Read before the National Academy of Sciences, Philadelphia, Nov. 15, 1881.]

Mean annual rain-fall for different countries of the globe.

WHEN we attempt to analyze the phenomena of storms, we immediately find evidence of the operation of general causes which are not peculiar to any particular storm. We see this truth illustrated by the tracks which storms pursue, and by the unequal amounts of rain which are precipitated at different places. In the case of any particular storm it is difficult to decide how much influence is to be ascribed to general causes, and how much to special causes. The influence of general causes is sometimes best shown by the averages derived from a large number of cases, by which means the peculiarities of particular storms are mostly eliminated. With this view I have undertaken to study the average annual distribution of rain for the entire globe. A comparison of the mean annual rain-fall for different localities shows unequivocally the influence of general causes quite distinct from the peculiarities of particular storms. These general causes must operate upon each storm, and a distinct understanding of their nature must assist

us in explaining the phenomena of particular storms. For many years I have been desirous of making a comparison of this kind, but have been prevented by the deficiency of observations of rain-fall for large portions of the earth's surface. Having at length succeeded in collecting observations from a pretty large number of stations, I have undertaken to compare them and to represent the results upon a map by lines of equal rain-fall. I am well aware that for certain portions of the globe (especially for the southern hemisphere), the observations are too few to enable us to draw the lines of equal rain-fall with confidence; yet I trust this imperfect effort may be useful in assisting us to understand the causes which influence the amount of rain-fall at particular localities.

The following table presents a portion of the results which I have collected, and the observations are divided into groups depending upon the amount of the mean annual rain-fall. The first group contains all the cases I have found in which the mean annual rain-fall exceeds 200 English inches; the second group contains cases in which the annual rain-fall is less than 200 inches, but greater than 150 inches; the third group contains cases of rain-fall from 150 to 100 inches; the fourth from 100 to 75 inches, the fifth from 75 to 50 inches, the sixth from 50 to 25 inches, the seventh from 25 to 10 inches, and the eighth group contains cases in which the mean annual rain-fall is less than 10 inches. This table shows all the stations I have found where the annual rain-fall is specially remarkable either for its great or for its small amount, and for those regions of the globe where only a few scattering observations have been found, all known cases have been inserted in the table; but for those countries where the stations of observation are numerous, only a small portion of the whole number have been retained. If I had inserted in my table the results for all known stations, the list would have filled a large volume. The number of stations in the United States at which the rain-fall has been measured is over 1200; the total number of rain-gauges now regularly observed in Great Britain is about 2200; and there are numerous stations of observation in every country of Europe. In British India the rain-fall has been measured at more than 350 stations, at many of which the observations have been continued for more than twenty years; in the islands of the Asiatic Archipelago, belonging to Holland, the rain-fall is measured at 124 stations; and there are numerous stations of observation in Australia, Africa and elsewhere. All available observations have been consulted in drawing the lines of equal rain-fall upon the accompanying map, but only a small part of them are contained in the following table.

Mean Annual Rain-fall for various stations.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
1	Cherapunji, Assam	4125	25 14 N.	91 46 E.	16–22	492·45	India, 1878, p. 116
2	Buxa Fort, Bengal	....	26 47 N.	89 36 E.	9–10	217·58	India, 1878, p. 115
3	Sandoway, Burmah	0	18 10 N.	94 5 E.	16–18	213·54	India, 1878, p. 120
4	Mahableshwar, Bombay	4540	17 56 N.	73 38 E.	22–24	253·24	India, 1878, p. 117
5	Baura, Bombay	....	16 29 N.	74 0 E.	5– 7	260·65	India, 1878, p. 117
6	Matheran, Bombay	....	19 0 N.	73 12 E.	10–13	255·41	India, 1878, p. 118
7	Uttray Mullay	4500	8 39 N.	77 0 E.	2	267·21	Phil. Trans., 1850, p. 358
8	Buitenzorg, Java	869	6 36 S.	106 47 E.	1	220·72	Bergsma, 1879, p. 217
9	Pelantoengan, Java	2274	7 6 S.	109 59 E.	1	235·64	Bergsma, 1879, p. 219
10	Oenarang, Java	1027	7 8 S.	110 23 E.	1	205·04	Bergsma, 1879, p. 219
11	Padang Pandjang, Sum.	2559	0 30 S.	100 30 E.	1	282·33	Bergsma, 1879, p 223
12	Amboina, Island	....	3 42 S.	128 10 E.	1	226·06	Bergsma, 1879, p. 225
13	Matouba, Guadeloupe	4000	16 5 N.	61 50 W.	1	292·33	Comp. Rend., v. 7, p. 743
14	San Luis de Maranhao	....	2 31 S.	44 18 W.	1	280·00	Humb's Tr., v. 5, p. 270
15	Sylhet, Assam	....	24 53 N.	91 47 E.	22–26	154·28	India, 1878, p. 116
16	Akyab, Burmah	20	20 8 N.	92 52 E.	21–22	196·63	India, 1878, p. 120
17	Kyouk Phyoo	0	19 24 N.	93 34 E.	13	170·30	India, 1878, p. 120
18	Moulmein, Burmah	87	16 29 N.	97 40 E.	29	189·39	India, 1878, p. 120
19	Tavoy, Burmah	0	14 7 N.	98 18 E.	21–22	193·83	India, 1878, p 121
20	Mergui, Burmah	0	12 33 N.	98 48 E.	14–15	150·55	India, 1878, p. 121
21	Rungbee	5000	27 N.	88 E.	4	170 5	Haughton, Ph. Geog.
22	Lanauli, Bombay	....	18 48 N.	73 26 E.	5	162·93	India, 1878, p. 117
23	Ratnapura, Ceylon	..	6 35 N.	80 22 E.	9	151·73	India, 1878, p. 120
24	Attaghery	2200	8 N.	77 E.	1	170	Phil. Trans., 1850, p. 362
25	Augusta Peak	6200	8 N.	77 E.	1	194	Phil. Trans., 1850, p. 362
26	Sindola, Bombay	4600	17 56 N.	73 39 E.	1	185·16	Phil. Trans., 1850, p 354
27	Magelang, Java	1256	7 29 S.	110 13 E.	1	160 64	Bergsma, 1879, p. 220
28	Bojolali, Java	1300	7 32 S.	110 35 E.	1	151·18	Bergsma, 1879, p. 220
29	Padang, Sumatra	0	0 58 S.	100 25 E.	1	181·39	Bergsma, 1879, p. 222
30	Siboga, Sumatra	0	1 44 N.	98 46 E.	1	172·36	Bergsma, 1879, p. 222
31	Singkel, Sumatra	0	2 17 N.	97 45 E	1	171·22	Bergsma, 1879, p. 222
32	Tandjong Pandan	0	2 45 S.	107 33 E.	1	153·27	Bergsma, 1879, p. 224
33	Sintang, Borneo	....	0 7 N.	111 32 E.	1	160·08	Bergsma, 1879, p. 224
34	Makassar, Celebes	0	5 8 S.	119 24 E	1	152·76	Bergsma, 1879, p. 224
35	Leogane, St. Domingo	....	18 30 N.	72 30 W.	.....	150	Malte-brun's Geo'y, v. i, p 359
36	Vera Cruz, Mexico	0	19 12 N.	96 9 W	9	183·20	Mayer's Mex., v. 2, p. 188
37	Marmato, N. Grenada	4678	5 33 N.	76 0 W.	2	162·80	Rep. Br. Ass., 1840, p. 116
38	Demerara, Guiana	...	6 45 N.	58 2 W.	.....	156·72	Berghaus, Phys. Atlas
39	Caracas, Colombia	2730	10 22 N.	67 5 W.	1	155·37	Dove Beitrage, p. 90
40	The Styo, England	1600	54 28 N.	3 13 W.	.....	189·45	Koner, v. 13, p. 105
41	Seathwayte, England	1334	54 29 N.	3 12 W.	.....	152·24	Koner, v. 13, p. 105
42	Kurseong, Bengal	....	26 54 N.	88 18 E.	4	140·67	India, 1878, p. 115
43	Darjeeling, Bengal	6912	27 3 N.	88 18 E.	18–21	118·24	India, 1878, p. 115
44	Mongpoo, Bengal	....	26 58 N.	88 24 E.	5– 6	119·44	India, 1878, p. 115
45	Julpigoree, Bengal	...	26 32 N.	88 50 E.	9–10	124·22	India, 1878, p. 115
46	Cooch Behar, Bengal	...	26 16 N.	89 29 E.	7– 8	129·95	India, 1878, p. 115
47	Chittagong, Bengal	90	22 21 N.	91 50 E.	20–24	103·73	India, 1878, p. 115
48	Noakhally, Bengal	...	22 52 N.	91 14 E.	20–22	107·45	India, 1878, p. 115
49	Silchar, Assam	87	24 48 N.	92 51 E.	21–22	117·54	India, 1878, p. 116
50	Tura, Assam	....	25 27 N.	90 18 E.	8– 9	122·46	India, 1878, p. 116
51	Dibrugarh, Assam	....	27 34 N.	95 2 E	15–18	114·45	India, 1878, p. 116
52	Shwe Gyen, Burmah	....	18 6 N.	96 46 E.	10	149·16	India, 1878, p. 121
53	Port Blair, Andamans	61	11 41 N.	92 42 E.	11	117·39	India, 1878, p. 121
54	Nancowry, Nicobars	81	8 0 N.	93 46 E.	5– 6	100·85	India, 1878, p. 121
55	Dharmsala, Punjab	....	32 19 N.	76 21 E.	19–20	126·29	India, 1878, p. 112

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
56	Igatpuri, Hyderabad	-- -	19 47 N.	73 35 E.	9–16	120·43	India. 1878, p. 117
57	Karwar, Bombay	44	14 45 N.	74 17 E.	17–18	115·54	India, 1878. p. 118
58	Honawar, Bombay	----	14 17 N.	74 30 E.	15–17	140·97	India. 1878. p. 118
59	Vingorla, Bombay	----	15 50 N.	73 40 E.	10–17	114·30	India, 1878, p. 118
60	Ratnagiri. Bombay	108	17 6 N.	73 23 E.	10–22	104·20	India, 1878, p. 118
61	Goa. Bombay	23	15 21 N.	73 56 E.	4	107·04	India, 1878, p. 118
62	Cochin. Madras	11	9 58 N.	76 17 E.	22–23	114·04	India, 1878, p. 120
63	Calicut, Madras	----	11 15 N.	75 32 E.	17–18	116·73	India, 1878, p. 120
64	Tellicherry, Madras	----	11 45 N.	75 32 E.	15–16	128·08	India. 1878, p. 120
65	Cannanore, Madras	----	11 52 N.	75 26 E.	17–18	135·34	India, 1878, p. 120
66	Mangalore, Madras	----	12 52 N.	74 54 E.	20–25	134·04	India, 1878, p. 120
67	Mercara. Mysore	----	12 30 N.	75 50 E.	15	119·94	India, 1878, p. 120
68	Allepy, Madras	30	9 27 N.	76 20 E.	5	113·26	Phil.Trans., 1850, p.358
69	Dodabetta. Madras	8640	11 23 N.	75 47 E.	1	101·24	Phil.Trans., 1850, p.358
70	Kundalla. Bombay	1740	18 40 N.	73 30 E.	2	141·59	Phil.Trans., 1850, p.356
71	Anjarakandy,	----	11 40 N.	75 40 E.	14	123·52	Dove Beiträge, p. 100
72	Tjandjoer, Java	1542	6 49 S.	107 8 E.	1	128·27	Bergsma, 1879, p. 217
73	Soekawana. Java	5062	6 45 S.	107 38 E.	1	117·88	Bergsma, 1879, p. 217
74	Kedong Kebo, Java	148	7 41 S.	110 2 E.	1	134·10	Bergsma, 1879, p. 219
75	Pekalongan, Java	----	6 53 S.	109 40 E.	1	104·37	Bergsma, 1879, p. 219
76	Semarang, Java	13	6 58 S.	110 25 E.	1	101·78	Bergsma, 1879, p. 219
77	Willem Island, Java	1562	7 16 S.	110 24 E.	1	113·16	Bergsma, 1879, p. 219
78	Salatiga, Java	1932	7 20 S.	110 30 E.	1	135·67	Bergsma, 1879, p. 219
79	Djokjokarta, Java	370	7 48 S.	110 21 E.	1	123·90	Bergsma, 1879, p. 221
80	Klatten, Java	692	7 42 S.	110 35 E.	1	110·99	Bergsma, 1879, p. 221
81	Soerakarta, Java	302	7 34 S.	110 49 E.	1	112·41	Bergsma, 1879, p. 221
82	Ngawi, Java	263	7 24 S.	111 26 E.	1	107·95	Bergsma, 1879, p. 221
83	Malang, Java	1476	7 57 S.	112 38 E.	1	136·30	Bergsma, 1879, p. 221
84	Maësan. Java	1214	8 0 S.	113 50 E.	1	139·41	Bergsma, 1879, p. 223
85	Benkoelen, Sumatra	----	3 47 S.	102 14 E.	1	130·51	Bergsma, 1879, p. 223
86	Tandjong Pinang	----	0 56 N.	104 25 E.	1	123·70	Bergsma, 1879, p. 225
87	Palembang. Sumatra	----	2 59 S.	104 45 E.	1	108·07	Bergsma, 1879, p. 225
88	Muntok. Sumatra	----	2 3 S.	105 9 E.	1	136·50	Bergsma, 1879, p. 225
89	Pontianak, Borneo	----	0 1 N.	109 20 E.	1	130·94	Bergsma, 1879, p. 225
90	Bandjermasin. Borneo	----	3 19 S.	114 35 E.	1	104·05	Bergsma, 1879, p. 225
91	Banda Isle	---	4 32 S.	129 53 E.	1	142·12	Bergsma, 1879, p. 225
92	Flagstaff Mountain	2245	5 25 N.	100 E.	-----	116·21	Berghaus Ph. Atlas
93	Fiji Islands	77	16 38 S.	178 37 E.	5	124·15	Q.J. Met.Soc., v.3. p.265
94	Navigators' Islands	----	13 50 S.	171 44 W.	-----	106	Q.J. Met.Soc., v.5. p.189
95	Hokitiki. New Zealand	----	42 42 S.	170 58 E.	4	111·65	Zeitschrift. v. 6. p. 345
96	Cafeiere du Perou. Gua.	----	16 5 N.	61 45 W.	19	126·74	Dove Beiträge. p. 92
97	Tivoli, San Domingo	----	19 0 N.	70 W.	2	107·47	Dove Beiträge, p. 93
98	Cape Haitien, S. Dom.	----	19 43 N	72 13 W.	-----	127·89	Berghaus Ph. Atlas
99	Grenada, W. Indies	---	12 9 N.	61 48 W.	3	107·73	Dove Beiträge, p. 92
100	Bath, Jamaica	170	18 0 N.	76 25 W.	2	136·46	Q. J. Met. Soc., v.4, p.16
101	Castleton. Jamaica	700	18 9 N.	76 50 W.	4	106·61	Q. J. Met. Soc., v.4, p.16
102	Cinchona, Jamaica	5100	18 3 N.	76 40 W.	4	104·83	Q. J. Met. Soc., v.4, p.16
103	New Castle, Jamaica	3974	18 3 N.	76 44 W.	4	100·01	Q. J. Met. Soc., v.4, p.16
104	Cayenne, Guyana	----	4 56 N.	52 30 W.	6	138·31	An.Met. de France.1853
105	Paramaribo, Guyana	----	5 45 N.	55 13 W.	5	142·45	Dove Beiträge, p. 90
106	Pernambuco. Brazil	----	8 10 S.	34 51 W.	1	106·07	Dove Beiträge, p. 90
107	Gongo Soco, Brazil	3357	19 58 S.	43 30 W.	2	115·74	Dove Beiträge, p. 94
108	Georgetown, Guyana	----	6 50 N.	58 4 W.	7	100·5	Dove Beiträge, p. 90
109	Cordoba, Mexico	878	18 51 N.	96 54 W.	9	112 9	Haughton. Ph. Geog.
110	Aspinwall, N. Granada	7	9 23 N.	79 53 W.	4	121·44	Schott's Tables, p. 83
111	Glenco, Scotland	----	56 39 N.	5 10 W.	-----	128·51	Koner, v. 13, p. 105
112	Skye, Scotland	----	57 20 N.	6 12 W.	-----	101·50	Koner, v. 13, p. 105

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
113	Coimbra, Portugal	----	40° 13′ N.	8° 25′ W.	-----	118·55	Dove Beiträge, p. 114
114	Freetown, W. Africa	250	8 29 N.	13 10 W.	5	125·80	Zeitschrift, v. 5. p. 122
115	Fernando Po, W. Africa	98	3 46 N.	8 28 W.	4	100·67	Q.J. Met.Soc., v. 2, p. 52
116	Bahr el Abiad, E. Afri.	----	9 N.	30 E.	-----	100·?	Johnston's Africa. p.571
117	Ft. Tongass, Alaska	25	54 46 N.	130 30 W.	2	118·3	Pacific Coast Pilot, p. 26
118	Neeah Bay, Wash. Ter.	40	48 22 N.	124 37 W.	3	123·35	Schott's Tables, p. 79
119	Valdivia, Chili	42	39 57 S.	73 28 W.	19	115·49	Zeitschrift, v. 11, p. 137
120	Mussoore, N. W. Prov.	---	30 25 N.	77 44 E.	14–26	95·21	India, 1878, p. 113
121	Naini Tal, N. W. Prov.	---	29 26 N.	79 36 E.	17–19	81 16	India, 1878, p. 112
122	Dinajpore, Bengal	----	25 36 N.	88 37 E.	19–21	77·18	India, 1878, p. 115
123	Rungpore, Bengal	----	25 44 N.	89 25 E.	18–22	86·67	India, 1878, p. 115
124	Bogra, Bengal	----	24 49 N.	89 26 E.	16–19	81·28	India, 1878, p. 115
125	Burrisal, Bengal	----	22 44 N.	90 20 E.	13–14	78·46	India, 1878, p. 115
126	Mymensing, Bengal	---	24 48 N.	90 30 E.	17–19	98·27	India, 1878, p. 115
127	Comillah, Bengal	----	23 33 N.	91 20 E.	21–22	92·56	India, 1878, p. 115
128	Rangamati, Bengal	----	22 32 N.	92 17 E.	10	97·57	India, 1878, p. 115
129	Agartalla, Bengal	----	23 52 N.	90 20 E.	6–7	77·77	India, 1878, p. 115
130	False Point, Bengal	15	20 20 N.	86 47 E.	12	75·02	India, 1878, p. 116
131	Sibsagar, Assam	332	26 59 N.	94 40 E.	22–24	93·98	India, 1878, p. 116
132	Goalpara, Assam	386	26 11 N.	90 40 E.	17	93·34	India, 1878, p. 116
133	Tezpur, Assam	----	26 44 N.	92 52 E.	21–25	76·06	India, 1878, p. 116
134	Nowgong, Assam	----	26 28 N.	92 45 E.	21–24	81·65	India, 1878, p 116
135	Shillong, Assam	----	25 36 N.	92 4 E.	12–13	86·93	India, 1878, p. 116
136	Rangoon, Burmah	40	16 46 N.	96 12 E.	9	99·69	India, 1878, p. 120
137	Bassein, Burmah	15	16 4 N.	94 50 E.	9	96·89	India, 1878, p. 120
138	Henzada, Burmah	----	17 45 N.	95 32 E.	8	75·09	India, 1878, p. 120
139	Pachumarhi, Cen. Prov.	3504	22 28 N.	78 28 E.	7– 8	80·93	India, 1878, p. 117
140	Byculla, Bombay	----	18 50 N.	72 49 E.	10–17	82·60	India, 1878, p. 118
141	Esplanade, Bombay	----	18 54 N	72 49 E.	10–17	77·00	India, 1878, p. 118
142	Tanna, Bombay	----	19 23 N.	72 49 E.	12–21	98·21	India, 1878, p. 118
143	Manantoddy, Madras	----	11 48 N.	76 0 E.	11	91·88	India, 1878, p. 120
144	Galle, Ceylon	40	6 1 N.	80 12 E.	9	91·69	India, 1878, p. 120
145	Colombo, Ceylon	40	6 56 N.	79 50 E.	9	88·82	India, 1878, p. 120
146	Kandy, Ceylon	1650	7 18 N.	80 35 E.	9	81·27	India, 1878, p. 120
147	Newera Elya, Ceylon	6150	7 0 N.	80 42 E.	8–9	99·45	India, 1878, p. 120
148	Quilon, Madras	30	8 54 N.	76 39 E.	5	76·76	Phil.Trans., 1850, p.357
149	Singapore, Malacca	---	1 42 N.	103 50 E.	10	91·66	India, 1878, p. 121
150	Serang, Java	102	6 7 S.	106 8 E.	4	81·02	Bergsma, 1879, p. 217
151	Tangerang, Java	33	6 10 S.	106 40 E.	1	79·41	Bergsma, 1879, p. 217
152	Batavia, Java	23	6 11 S.	106 50 E.	6	78·91	Batavia Obs., p. 64
153	Meester Cornelis, Java	46	6 13 S.	106 54 E.	1	78·78	Bergsma, 1879, p. 217
154	Tegal, Java	0	6 51 S.	109 8 E.	1	95 56	Bergsma, 1879, p. 219
155	Toeban, Java	0	6 52 S.	112 5 E.	1	88·70	Bergsma, 1879, p. 219
156	Modjokerto, Java	95	7 28 S.	112 25 E.	1	96·70	Bergsma, 1879, p. 221
157	Soerabaja, Java	0	7 14 S.	112 44 E.	1	92·64	Bergsma, 1879, p. 221
158	Grissee, Java	0	7 10 S.	112 39 E.	1	91·46	Bergsma, 1879, p. 221
159	Bangkalan, Java	16	7 2 S.	112 44 E.	1	96·74	Bergsma, 1879, p. 221
160	Pamekasan, Java	0	7 10 S.	113 30 E.	1	82·48	Bergsma, 1879, p. 221
161	Soemenep, Java	0	7 3 S.	113 54 E.	1	83·07	Bergsma, 1879, p. 221
162	Pasoeroean, Java	13	7 38 S	112 56 E.	1	75·20	Bergsma, 1879, p. 221
163	Besoeki, Java	7	7 43 S.	113 41 E.	1	83·15	Bergsma, 1879, p. 221
164	Sitoebondo, Java	262	7 41 S.	114 2 E.	1	77·87	Bergsma, 1879, p. 223
165	Banjoewangi, Java	16	8 13 S.	114 23 E.	1	88·50	Bergsma, 1879, p. 223
166	Telok Betong, Sumatra	0	5 26 S.	105 16 E.	1	88·86	Bergsma, 1879, p. 223
167	Solok, Sumatra	1234	0 48 S.	100 40 E.	1	83·11	Bergsma, 1879, p. 223
168	Pajakombo, Sumatra	1630	0 15 S.	100 47 E.	1	83·38	Bergsma, 1879, p. 223

Mean Annual Rain-fall for various stations—Continued.

No	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
169	Medan Poetri, Sumatra	46	3 35 N.	98 41 E.	1	84·41	Bergsma, 1879, p. 225
170	Djambi, Sumatra	0	1 35 S.	103 36 E.	1	96·85	Bergsma, 1879, p. 225
171	Hong Kong, China	....	22 20 N.	114 13 E.	1	79·02	Dove Beiträge, p. 102
172	Canton, China	....	23 15 N.	113 16 E.	....	77 64	Dove Beiträge, p. 102
173	Manilla, Phil. Is.	69	14 36 N.	120 40 E.	1	76·00	International Bulletin
174	Reunion, Isle Bourbon	131	20 50 S.	55 30 E.	6	79·18	Zeitschrift, v. 9, p. 334
175	Southport, Australia	....	12 44 S.	131 0 E.	1	76·89	Todd, S. Aust., p. 126
176	Kingstown, St. Vincent	....	13 13 N.	61 18 W.	.....	82·78	Dove Beiträge, p. 92
177	St. Vincent, W. I.	....	13 15 N.	61 18 W.	6	78·17	Dove Beiträge, p. 92
178	Martinique, W. I.	....	14 50 N.	61 3 W.	.....	86 93	Gehler's Ph. Wör., v. 7
179	Havana, Cuba	50	23 9 N.	82 23 W.	7	91·37	Dove Beiträge, p. 93
180	Philipsburg, St. Martin	....	18 5 N.	63 3 W.	3	86·32	Schott's Tables, p. 81
181	Stony Hill, Jamaica	1425	18 4 N.	76 49 W.	5	80·53	Q. J. Met. Soc., v.4, p.16
182	Mandeville, Jamaica	2130	18 1 N.	77 32 W.	7	86·58	Q. J. Met. Soc., v.4, p.16
183	Salter's Hill, Jamaica	889	18 19 N.	77 48 W.	5	77·41	Q. J. Met. Soc., v.4, p.16
184	Georgetown, Br. Gu.	....	6 41 N.	58 11 W.	11	95·03	Sandeman's Obs.
185	Tlacotalpam, Mexico	11	18 37 N.	95 39 W.	1	89·10	International Bulletin
186	Rustenburg, Guyana	....	5 N.	55 W.	3	97·38	Schott's Tables, p. 83
187	Mt. Washington, N. H.	6286	44 16 N.	71 16 W.	8	77·23	Signal Service Obs.
188	Cape Hatteras, N. C.	....	35 14 N.	75 30 W.	4	78·40	Signal Service Obs.
189	Catharina, Surinam	....	5 48 N.	56 47 W.	4	77·94	Schott's Tables, p. 83
190	San Antonio, Brazil	....	9 5 S.	64 0 W.	1	91·27	Zeitschrift, v. 15, p. 492
191	Mirador, Mexico	3035	19 13 N.	96 50 W.	8	84·70	Haughton, Ph. Geog.
192	St. Maria, Alps	5936	46 34 N.	8 46 E.	.....	97·76	Koner, v. 13, p. 105
193	Stubenbach, Bavaria	....	49 6 N.	13 23 E.	.....	86·54	Koner, v. 13, p. 105
194	Liknoes, Norway	....	61 30 N.	4 41 E.	.....	85·47	Koner, v. 13, p. 105
195	Cape Palmas, W. Africa	....	4 22 N.	7 44 W.	.....	82·07	Berghaus Ph. Atlas
196	Sierra Leone, W. Africa	....	8 20 N.	13 8 W.	....	86·26	Dove Beiträge, p. 91
197	Astoria, Oregon	50	46 11 N.	123 49 W.	1	86·35	Schott's Tables, p. 77
198	Fort Stevens, Oregon	....	46 12 N.	123 57 W.	1	85·82	Schott's Tables, p. 77
199	Blockhouse, Oregon	....	44 25 N.	123 30 W.	1	96·29	Schott's Tables, p. 77
200	Sitka, Alaska	20	57 3 N.	135 18 W.	30	81·69	Pacific Coast P., p. 26
201	Marbato, N. Grenada	4836	5 29 N.	76 0 W.	15	90·	Proc. Br. Met. Soc., v. 3
202	Conception, Chili	33	36 46 S.	73 9 W.	2	93·15	Zeitschrift, v. 11, p. 137
203	Corral, Chili	33	39 53 S.	72 W.	3	99·68	Zeitschrift, v. 11, p. 137
204	Puerto Montt, Chili	33	41 30 S.	73 W	10	96·37	Zeitschrift, v. 11, p. 137
205	Simla, Punjab	6952	31 6 N.	77 12 E.	16–17	70·20	India, 1878, p. 112
206	Mount Abu, Rajputana	....	24 38 N.	72 43 E.	19	62·36	India, 1878, p. 112
207	Debra, N. W. Prov.	2232	30 20 N.	78 8 E.	21	70·76	India, 1878, p. 113
208	Khatmandu, Nepal	...	27 41 N.	85 23 E.	24–28	55·90	India, 1878, p. 114
209	Budwan, Bengal	99	23 14 N.	87 54 E.	18–19	58·58	India, 1878, p. 114
210	Bankoora, Bengal	..	23 15 N.	87 12 E.	21–24	55·31	India, 1878, p. 114
211	Soory, Bengal	...	23 53 N.	87 34 E.	16–19	55·65	India, 1878, p. 114
212	Calcutta, Bengal	18	22 33 N.	88 21 E.	49–50	65·80	India, 1878, p. 115
213	Krishnaghur, Bengal	...	23 24 N.	88 38 E.	15–18	56·37	India, 1878, p. 115
214	Jessore, Bengal	33	23 9 N.	89 7 E.	19–24	68·96	India, 1878, p. 115
215	Berhampore, Bengal	66	24 6 N.	88 17 E.	24–26	55·55	India, 1878, p. 115
216	Maldah, Bengal	....	24 58 N.	88 19 E.	21–23	53·52	India, 1878, p. 115
217	Baulea, Bengal	....	24 26 N.	88 38 E.	20–24	60·00	India, 1878, p. 115
218	Pubna, Bengal	.	24 4 N.	89 19 E.	15–17	68·51	India, 1878, p. 115
219	Dacca, Bengal	...	23 43 N.	90 27 E.	28–30	73·22	India, 1878, p 115
220	Cuttack, Bengal	. 80	20 29 N.	85 54 E.	18–21	55·60	India, 1878, p 116
221	Pooree, Bengal	....	19 48 N.	85 58 E.	21–24	55·26	India, 1878, p. 116
222	Balasore, Bengal	...	21 30 N.	87 0 E.	19–21	66·47	India, 1878, p. 116
223	Gauhati, Assam	....	26 14 N.	91 48 E.	27–30	69·21	India, 1878, p. 116
224	Jubbulpore, C. Prov.	1351	23 9 N.	79 59 E.	33–35	52·32	India, 1878, p. 116

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
225	Colaba, Bombay	37	18 54 N.	72 49 E.	32–62	74·20	India. 1878, p. 118
226	Palghat, Madras	...	10 46 N.	76 45 E.	16	71·52	India, 1878, p. 120
227	Trevandrum	130	8 30 N.	77 E.	8	69·42	Dove Beiträge. p. 100
228	Onrust, Java	....	6 1 S.	106 46 E.	1	71·42	Bergsma, 1879, p. 217
229	Rembang, Java	....	6 45 S.	111 20 E.	1	67·92	Bergsma, 1879, p. 219
230	Probolingo, Java	33	7 44 S.	113 13 E.	1	67·84	Bergsma, 1879, p. 221
231	Fort de Kock, Sumatra	3041	0 21 S.	100 28 E.	1	74·53	Bergsma, 1879, p. 223
232	Kotta Radja, Sumatra	....	5 32 N.	95 20 E.	1	53·27	Bergsma, 1879, p. 223
233	Pulo Penang	....	5 25 N.	100 19 E.	.....	65·06	Berghaus' Ph. Atlas
234	Macao, China	...	22 15 N.	113 34 E.	14	69·10	Dove Beiträge. p. 102
235	Tokio, Japan	66	35 43 N.	139 46 E.	8	65·3	Zeitschrift, v. 15, p. 439
236	Petro Paulovsk	40	53 0 N.	158 39 E.	3	61·1	Russian Met. Annalen
237	Brisbane, N. S. W.	...	27 32 S.	153 2 E.	12	50·5	Haughton, Ph. Geog.
238	Sydney, N. S. W.	....	33 52 S.	151 15 E.	33	50·63	Zeitschrift, v. 10, p. 356
239	King's Island, Aust.	135	39 35 S.	144 5 E.	5	58·66	Zeitschrift, v. 7, p. 394
240	Mackay, Queensland	200	21 10 S.	149 5 E.	4	74·84	Q. J. Met. Soc., v. 7, p. 9
241	Napoleonville, N. Cal.	..	21 30 S.	166 0 E.	2	63·39	An. Met. de France, 1867
242	Nelson, N. Zealand	18	41 15 S.	173 18 E.	7	61·60	Zeitschrift, v. 6, p. 345
243	Tarmaki, N. Zealand	....	39 2 S.	174 5 E.	9	59·44	Zeitschrift, v. 6, p. 345
244	Mongonui, N. Zealand	....	35 42 S.	173 37 E.	4	58·14	Zeitschrift, v. 6, p 345
245	Wellington, N. Zealand	....	41 15 S.	174 45 E.	8	51·60	Zeitschrift, v. 6, p. 345
246	Gando, West Africa	....	10 N.	4 E.	.....	60·	Johnston's Af., p. 568
247	Freetown, W. Africa	....	8 29 N.	13 15 W.	.....	69·	Johnston's Af., p. 568
248	Bambarre, C. Africa	....	4 37 S.	27 52 E.	.....	58·	Johnston's Af., p. 577
249	Zanzibar, East Africa	44	5 45 S.	39 10 E.	5	61·02	Q.J. Met.Soc., v. 6, p. 32
250	Lagos, West Africa	....	7 31 N.	3 28 E.	1	57·56	Zeitschrift, v. 13, p. 416
251	Lenkoran, Caucasus	75	38 44 N.	48 53 E.	7	51·74	Koner, v. 13, p. 105
252	Kutais, Caucasus	....	42 20 N.	42 50 E.	7	58·90	Koner, v. 13, p. 105
253	Redut Kale, Caucasus	....	42 16 N.	41 36 E.	.....	60·36	Koner, v. 13, p. 105
254	Ragusa, Eu. Turkey	....	42 38 N.	18 7 E.	.....	65·71	Koner, v. 13, p. 107
255	Fiume, Austria	....	45 20 N.	14 26 E.	.....	64·96	Koner, v. 13, p. 107
256	Alt Aussee, Alps	....	47 38 N.	13 47 E.	.....	66·22	Koner, v. 13, p. 108
257	Tolmezzo, Alps	....	46 24 N.	13 3 E.	.....	74·65	Koner, v. 13, p. 108
258	Camajore, Italy	....	43 48 N.	10 23 E.	.....	53·42	Koner, v. 13, p. 108
259	Klausthal, Hanover	....	51 48 N.	10 20 E.	.....	56·18	Koner, v. 13, p. 108
260	Isny, Alps	....	47 41 N.	10 3 E.	.....	54·84	Koner, v. 13, p. 108
261	Genoa, Italy	....	44 25 N.	8 56 E.	.....	55·01	Koner, v. 13, p. 168
262	Freudenstadt, Wurt.	....	48 28 N.	8 22 E.	....	55·95	Koner, v. 13, p. 108
263	Baden, Baden	....	48 45 N.	8 15 E.	.....	56·85	Koner, v. 13, p. 108
264	Chamberry, France	....	45 34 N.	5 53 E.	....	64·96	Koner, v. 13, p. 108
265	Bougia, Algeria	....	36 40 N.	5 5 E.	.....	51·77	Koner, v. 13, p. 108
266	Bergen, Norway	....	60 23 N.	5 20 E.	.....	72·68	Koner, v. 13, p. 106
267	Bagneres, Pyrenees	....	42 49 N.	0 35 E.	.....	58·66	Koner, v. 13, p. 107
268	Bayonne, Pyrenees	....	43 30 N.	1 30 W.	.....	56·30	Koner, v. 13, p. 107
269	Vergara, Spain	....	43 5 N.	2 18 W.	.....	51 18	Koner, v. 13, p. 107
270	Santiago, Spain	....	42 52 N.	8 23 W.	.....	67·60	Koner, v. 13, p. 107
271	Oporto, Portugal	....	41 9 N.	8 36 W.	....	57·68	Koner, v. 13, p. 107
272	Ancliffe, England	....	54 10 N.	2 8 W.	.....	59·49	Koner, v. 13, p. 106
273	Galway, Ireland	....	53 17 N.	9 4 W.	.....	50·99	Koner, v. 13, p. 106
274	Thorshavn, Faroe	....	62 2 N	6 44 W.	....	61·22	Danish Met. Obs.
275	Faial, Azores	....	37 40 N.	28 50 W.	2	58·70	Zeitschrift, v. 6, p. 411
276	Heart's Content	22	47 53 N.	53 21 W.	2	54·3	Canada Met. Obs.
277	St. Johns, N. F.	150	47 34 N	52 42 W.	4	51·9	Canada Met Obs.
278	Glace Bay, N. S.	34	46 12 N	59 58 W.	2	50·2	Canada Met. Obs.
279	Sydney, N. S.	37	46 8 N.	60 10 W.	4	50·6	Canada Met. Obs.
280	St. John, N. B.	150	45 17 N.	66 3 W.	4	50·2	Canada Met. Obs.
281	Halifax, N. S.	122	44 39 N.	63 36 W.	4	54·3	Canada Met. Obs.

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
282	Perry, Me.	100	45° 0′ N.	67 6 W.	9	50·29	Schott's Tables, p. 17
283	Steuben, Me.	50	44 31 N.	67 58 W.	12	53·36	Schott's Tables, p. 17
284	Fayetteville, Vt.	280	42 56 N.	72 40 W.	7	55·17	Schott's Tables, p. 19
285	Southwick, Ms.	265	42 2 N.	72 48 W.	2	52 50	Schott's Tables, p. 21
286	Wallingford, Ct.	133	41 27 N.	72 50 W.	5	52·03	Schott's Tables, p. 23
287	Ceres, Penn.	1440	42 0 N.	78 25 W	4	54·78	Schott's Tables, p. 33
288	Berwick, Penn.	583	41 5 N.	76 15 W.	2½	56·32	Schott's Tables, p. 35
289	Poplar Grove, W. Va.	720	38 20 N.	81 26 W.	3	55·84	Schott's Tables, p. 39
290	Camden, S. C.	275	34 17 N.	80 33 W.	8	50·56	Schott's Tables, p. 41
291	Fulton, S. C.	150	33 40 N.	80 31 W.	7	54·31	Schott's Tables, p. 41
292	Sparta, Ga.	550	33 17 N.	83 9 W.	9	54·11	Schott's Tables, p. 43
293	Culloden, Ga.	825	32 51 N.	84 13 W.	2	64·24	Schott's Tables, p. 43
294	Atlanta, Ga.	1050	33 45 N.	84 18 W.	2	58·43	Schott's Tables, p. 43
295	Ft. Barrancas, Fla.	20	30 21 N.	87 18 W.	8	57·20	Schott's Tables, p. 43
296	Jacksonville, Fla.	14	30 20 N.	81 39 W.	6	52·72	Schott's Tables, p. 43
297	Ft. Brooks, Fla.	20	28 0 N.	82 28 W.	17	53·63	Schott's Tables, p. 43
298	Ft. Pierce, Fla.	30	27 30 N.	80 20 W.	6½	58·02	Schott's Tables, p. 43
299	Ft. Myers, Fla.	50	26 38 N.	82 0 W.	7	56·55	Schott's Tables, p. 43
300	Ft. Dallas, Fla.	20	25 55 N.	80 20 W.	3½	59 04	Schott's Tables, p. 45
301	Huntsville, Ala.	600	34 43 N.	86 46 W.	12	54·88	Schott's Tables, p. 45
302	Greensborough, Ala.	350	32 40 N.	87 34 W.	16	51·67	Schott's Tables, p. 45
303	Monroeville, Ala.	150	31 33 N.	87 25 W.	5	60·89	Schott's Tables, p. 45
304	Mt. Vernon, Ala.	200	31 12 N.	88 2 W.	15	66·14	Schott's Tables, p. 45
305	Columbus, Mis.	227	33 30 N.	88 28 W.	5	57·13	Schott's Tables, p. 45
306	Natchez, Mis.	264	31 34 N.	91 25 W.	18	53·37	Schott's Tables, p. 45
307	Jackson, Mis.	350	32 23 N.	90 8 W.	4	54·60	Schott's Tables, p. 47
308	Monroe, La.	100	32 20 N.	92 10 W.	10	54·00	Schott's Tables, p. 47
309	West Feliciana, La.	96	30 38 N.	91 20 W.	13	61·34	Schott's Tables, p. 47
310	Baton Rouge, La.	41	30 26 N.	91 18 W.	15	60·16	Schott's Tables, p. 47
311	New Orleans, La.	10	29 57 N.	90 1 W.	18	51·03	Schott's Tables, p. 47
312	Nashville, Tenn.	533	36 10 N.	86 49 W.	7	52·02	Schott's Tables, p. 51
313	Washington, Ark.	660	33 41 N.	93 41 W.	22	54·50	Schott's Tables, p. 51
314	Welchfield, O.	1205	41 23 N.	81 12 W.	8½	51·94	Schott's Tables, p. 55
315	Sandwich, Ill.	665	41 31 N.	88 30 W.	7½	50·17	Schott's Tables, p. 61
316	Ft. Towson, Ind. T.	300	34 0 N.	95 33 W.	14	51·08	Schott's Tables, p. 69
317	Camp Gaston, Cal.	----	41 10 N.	123 15 W.	4½	62·20	Schott's Tables, p. 77
318	Meadow Valley, Cal.	4000	40 20 N.	120 15 W.	4½	57·03	Schott's Tables, p. 77
319	Ft. Umpqua, Or.	8	43 42 N.	124 10 W.	6	67·41	Schott's Tables, p. 77
320	Ft. Hoskins, Or.	----	45 2 N.	123 32 W.	6½	66·71	Schott's Tables, p. 77
321	Ft. Yamhill, Or.	----	45 21 N.	123 30 W.	9	55·59	Schott's Tables, p. 77
322	Ft. Cascades, Wash. T.	----	45 39 N.	121 50 W.	3	64·57	Schott's Tables, p. 79
323	Ft. Wrangell, Alaska	30	56 16 N.	132 29 W.	3	60·5	Pacific C. Pilot, p. 26
324	St. Paul Kadiak, Al.	22	57 47 N.	152 20 W.	1	72·9	Pacific C. Pilot, p. 26
325	Matsqui, Br. Col.	50	49 7 N.	122 16 W.	1	61·1	Canada Met. Obs.
326	New Westminster, B.C.	33	49 12 N.	122 53 W.	2	58·4	Canada Met. Obs.
327	Hope, Br. Col.	130	49 23 N.	121 28 W.	2	53·6	Canada Met. Obs.
328	St. George's, Bermuda	123	32 23 N.	64 40 W.	6½	57·31	Schott's Tables, p. 81
329	Nassau, Bahamas	----	25 5 N.	77 21 W.	2	52·3	Dove Beiträge, p. 93
330	Matansas, Cuba	50	23 2 N.	81 38 W.	1	55·29	Schott's Tables, p. 81
331	Tuxpam, Mexico	----	19 0 N.	97 7 W.	1	62·7	Mex. Met. Obs.
332	Frontera, Mexico	12	18 32 N.	92 40 W.	2	72·51	Schott's Tables, p. 81
333	Tortola, W. I.	916	18 20 N.	64 32 W.	-----	65·17	Berghaus' Ph. Atlas
334	Port au Prince, Hayti	171	18 37 N.	72 17 W.	4½	60·96	Schott's Tables, p. 81
335	San Juan, Portorico	----	18 26 N.	65 39 W.	4	55·26	Zeitschrift, v. 9, p. 222
336	Linstead, Jamaica	403	18 7 N.	77 2 W.	2	60·32	Q.J. Met.Soc., v. 4, p. 15
337	Ellerslie, Jamaica	2000	18 3 N.	76 45 W.	2	66·70	Q.J. Met.Soc., v. 4, p. 15
338	Chapelton, Jamaica	----	18 3 N.	77 17 W.	5	56·11	Q.J. Met.Soc., v. 4, p. 15

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
339	Hope, Jamaica	650	18 2 N.	76 44 W.	4	50·95	Q.J. Met.Soc., v. 4, p. 15
340	Black River, Jamaica	....	17 58 N.	77 52 W.	5	56·12	Q.J. Met.Soc., v. 4, p. 15
341	Morant Point, Jamaica	....	17 56 N.	76 28 W.	7	64·58	Q.J. Met.Soc., v. 4, p. 15
342	Belize, Cent. Am.	....	17 29 N.	88 13 W.	6	72·35	Schott's Tables, p. 81
343	Pointe a Pitre, Guad.	....	16 16 N.	61 32 W.	19	71·62	Dove Beiträge, p. 92
344	Guatemala, C. Am.	4856	14 38 N.	90 28 W.	4	53·1	Schott's Tables, p. 81
345	Barbadoes, W. I.	....	13 10 N.	59 37 W.	25	57·7	Haughton, Ph. Geog
346	Near Kingstown, S. V.	....	13 13 N.	60 W.	.....	67·16	Dove Beiträge, p. 92
347	Trinidad, W. I.	...	10 28 N.	60 28 W.	.....	62·92	Berghaus' Ph. Atlas
348	San Jose, Costa Rica	3757	9 56 N.	84 0 W.	14	58·7	Hazen
349	LaBaja, N. Gren.	...	7 22 N.	72 30 W.	6	54·1	Proc. Br. Met. Soc., v. 3
350	Para, Brazil	....	1 25 S.	48 30 W.	1	71·41	Dove Beiträge, p. 90
351	Ciara, Brazil	....	3 52 S.	38 34 W.	28	52·84	Nature, v. 18, p. 384
352	Rio Janeiro, Brazil	....	23 0 S.	43 16 W.	6½	53·06	Dove Beiträge, p. 94
353	Aneud, Chili	49	41 51 S.	73 13 W.	3	52·01	Zeitschrift, v. 11, p. 137
354	Delhi, Punjab	718	28 40 N.	77 16 E.	28–29	27·20	India, 1878, p. 112
355	Lucknow, Oudh	369	26 50 N.	81 0 E.	8–11	41·69	India, 1878, p. 114
356	Benares, N. W. Prov.	267	25 20 N.	83 2 E.	22	39·92	India, 1878, p. 114
357	Surat, Bombay	36	21 13 N.	72 46 E.	10–16	42·74	India, 1878, p. 118
358	Nagpur, C. Prov.	1025	21 9 N.	79 11 E.	31–32	43·43	India, 1878, p. 116
359	Poona, Bombay	2000	18 28 N.	74 10 E.	23	30·41	India, 1878, p. 117
360	Hydrabad	....	17 27 N.	78 40 E.	10	29·27	India, 1878, p. 117
361	Madras	22	13 5 N.	80 17 E.	66	48·51	India, 1878, p. 119
362	Trichinopoly, Madras	275	10 50 N.	78 44 E.	25–27	38·70	India, 1878, p. 119
363	Ajansk, Russia	....	56 27 N.	138 26 E.	4	34·06	Rep. für Met., v.1, p.175
364	Hakodadi, Japan	90	41 47 N.	140 45 E.	4	43·6	Pacific C. Pilot, p. 26
365	Yokohama, Japan	656	35 27 N.	139 40 E.	1	41·7	Annuaire Met.deFrance
366	Zikawei, China	....	31 12 N	121 26 E.	4	42·21	Bolletino Mens., v. 1
367	Algir	2000	43 5 N.	44 19 E.	10	38·94	Rep. für Met., v.1,p. 175
368	Constantinople, Turkey	....	41 2 N.	28 58 E.	....	27·56	Koner, v. 13, p. 108
369	Beirut, Syria	....	33 54 N.	35 29 E.	2	40·5	Jahrb. für Met., 1876
370	Gothenburg, Sweden	....	57 44 N.	12 0 E.	.....	32·56	Koner, v. 13, p. 106
371	Aberdeen, Scotland	....	57 9 N.	2 7 W.	.....	29·44	Koner, v. 13, p. 106
372	Edinburgh, Scotland	....	55 57 N.	3 12 W.	.....	27·00	Koner, v. 13, p. 106
373	Manchester, England	....	53 31 N.	2 16 W.	.....	34·06	Koner, v. 13, p. 106
374	Dublin, Ireland	....	53 21 N.	6 16 W.	.....	29·21	Koner, v. 13, p. 106
375	Cork, Ireland	....	51 55 N.	8 26 W.	.....	41·73	Koner, v. 13, p. 106
376	Hamburg, Germany	....	53 33 N.	9 58 E.	.....	28·82	Koner, v. 13, p. 106
377	Utrecht, Holland	....	52 6 N.	5 8 E.	.....	30·40	Koner, v. 13, p. 106
378	Plymouth, England	....	50 22 N.	4 9 W.	.....	44·38	Koner, v. 13, p. 106
379	Brest, France	....	48 22 N.	4 29 W.	.....	28·35	Koner, v. 13, p. 106
380	Rouen, France	....	49 27 N.	1 4 E.	.....	25·59	Koner, v. 13, p. 107
381	Munich, Bavaria	...	48 8 N.	11 35 E.	.....	29·09	Koner, v. 13, p. 108
382	Salzburg, Aust.	....	47 49 N.	13 0 E.	.....	41·77	Koner, v. 13, p. 108
383	Geneva, Switz.	....	46 21 N.	6 32 E.	.....	29·53	Koner, v. 13, p. 108
384	Milan, Italy	....	45 28 N.	9 11 E.	.....	38·04	Koner, v. 13, p. 107
385	Trieste, Austria	....	45 39 N.	13 49 E.	.....	43·90	Koner, v. 13, p. 107
386	Montpelier, France	....	43 35 N.	3 53 E.	.....	29·13	Koner, v. 13, p. 107
387	Lisbon, Portugal	....	38 43 N.	9 10 W.	.....	26·77	Koner, v. 13, p. 107
388	Florence, Italy	....	43 46 N.	11 15 E.	.....	36·73	Koner, v. 13, p. 107
389	Rome, Italy	....	41 54 N.	12 29 E.	.....	30·91	Koner, v. 13, p. 107
390	Naples, Italy	....	40 53 N.	14 14 E.	.....	30·99	Koner, v. 13, p. 107
391	Gibraltar, spain	....	36 7 N.	5 20 W.	.....	29·73	Koner, v. 13, p. 107
392	Algiers, N. Africa	...	36 52 N.	3 2 E.	.....	31·10	Koner, v. 13, p. 107
393	Gondar, Abyssinia	....	12 36 N.	37 31 E.	.....	37·38	Berghaus' Ph. Atlas
394	Victoria, Nyanza	....	0	33 E.	.....	49·	Johnston's Af., p. 573

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
395	Bangweolo, C. Africa	----	11 ′ S.	29 ′ E.	2	47·5	Johnston's Af., p. 577
396	Mauritius Is.	----	20 27 S.	57 31 E.	2	32·42	Dove Beiträge, p. 102
397	Port Louis, Mauritius	30	20 10 S.	57 30 E.	13	35·63	Zeitschrift, v. 7, p. 205
398	Tete, South Africa	250	16 10 S.	33 30 E.	1	33·55	Zeitschrift, v. 7, p. 205
399	Port de France, N. Cal.	---	22 20 S.	166 39 E.	2	18·27	An. Met. de France, 1867
400	Maritzburg, Natal	2095	29 30 S.	30 2 E.	10	30·35	Q. J. Met. Soc., v. 7, p. 5
401	Gardenscliffe, Natal	2270	29 38 S.	30 30 E.	13	35·81	Q. J. Met. Soc., v. 7, p. 5
402	Merebank, Natal	30	29 55 S.	30 55 E.	9	44·21	Q. J. Met. Soc., v. 7, p. 5
403	Ottawa, Natal	300	29 38 S.	31 7 E.	10	38·98	Q. J. Met. Soc., v. 7, p. 5
404	Durban, Natal	130	29 50 S.	31 0 E.	7	42·05	Q. J. Met. Soc., v. 7, p. 5
405	King Williamst'n, S.Af.	2100	32 51 S.	27 37 E.	10	28·23	Q. J. Met. Soc., v. 7, p. 5
406	Grahamstown, S. Af.	1800	33 20 S.	26 33 E.	18	28·73	Q. J. Met. Soc., v. 7, p. 5
407	Capetown, S. Af.	50	33 55 S.	18 25 E.	16	26·77	Q. J. Met. Soc., v. 7, p. 5
408	Wynberg, S. Af.	200	34 1 S.	18 28 E.	14	42·65	Q. J. Met. Soc., v. 7, p. 5
409	Somerset, S. Af.	120	34 5 S.	18 52 E.	5	25·01	Q. J. Met. Soc., v. 7, p. 5
410	Simonstown, S. Af.	----	34 12 S.	18 26 E.	7	29 20	Q. J. Met. Soc., v. 7, p. 5
411	Mt. Lofty, S. Aust.	----	34 55 S.	138 51 E.	12	40·99	Zeitschrift, v. 9, p. 202
412	Mt. Barker, S. Aust.	----	35 0 S.	139 3 E.	9	27·33	Zeitschrift, v. 9, p. 202
413	Robetown, S. Aust.	----	37 3 S.	139 42 E.	9	25 44	Zeitschrift, v. 9, p. 202
414	Penola, S. Aust.	----	37 23 S.	140 59 E.	9	30·40	Zeitschrift, v. 9, p. 202
415	Mt. Gambier, S. Aust.	----	37 51 S.	140 53 E.	9	34·29	Zeitschrift, v. 9, p. 202
416	Beechworth, Victoria	1783	36 24 S.	146 24 E.	4½	29·29	Zeitschrift, v. 7, p. 293
417	Ararat, Victoria	1072	37 18 S.	142 54 E.	3	27·12	Zeitschrift, v. 7, p. 293
418	Ballarat, Victoria	1438	37 36 S.	143 54 E.	8½	27·21	Zeitschrift, v. 7, p. 293
419	Gabo Island, Victoria	40	37 36 S.	149 54 E.	2½	34·60	Zeitschrift, v. 7, p. 293
420	Buninyong, Victoria	----	37 42 S.	143 54 E.	3	26·02	Zeitschrift, v. 7, p. 293
421	Camperdown, Victoria	770	38 12 S.	143 12 E.	5⅝	30·48	Zeitschrift, v. 7, p. 293
422	Portland, Victoria	37	38 24 S.	141 36 E.	7	31·97	Zeitschrift, v. 7, p. 293
423	Port Albert, Victoria	30	38 36 S.	146 42 E.	3½	35·59	Zeitschrift, v. 7, p. 293
424	Melbourne, Victoria	121	38 48 S.	145 0 E.	17	27·45	Zeitschrift, v. 7, p. 293
425	Cape Otway, Victoria	300	38 54 S.	143 50 E.	2½	43·62	Zeitschrift, v. 7, p. 293
426	Kent's Group, Is.	280	39 29 S.	147 15 E.	5	30·40	Zeitschrift, v. 7, p. 394
427	Launceston, Tasmania	142	41 27 S.	147 8 E.	3	31·97	Zeitschrift, v. 7, p. 394
428	Swansea, Tasmania	18	42 8 S.	148 5 E.	3	26·97	Zeitschrift, v. 7, p. 394
429	Port Arthur, Tasmania	55	43 9 S.	147 54 E.	5	45·75	Zeitschrift, v. 7, p. 394
430	South Bruni, Tasmania	250	43 30 S.	147 10 E.	5	40 48	Zeitschrift, v. 7, p. 394
431	Stykkisholm, Iceland	----	65 5 N.	22 46 W.	-----	25·85	Danish Met Obs.
432	Berufiord, Iceland	----	64 40 N.	14 15 W.	-----	40·74	Danish Met. Obs.
433	Reikiavig, Iceland	36	64 9 N.	20 0 W.	7	28·94	Danish Met. Obs.
434	Angra, Azores	----	38 38 N.	27 15 W.	6	42·17	Zeitschrift, v. 6, p. 411
435	St. Michael, Azores	----	37 45 N.	25 15 W.	10	31·40	Dove Beiträge, p. 106
436	Madeira Is.	50	32 30 N.	17 30 W.	4	27·5	Dove Beiträge, p. 106
437	Funchal, Madeira	----	32 28 N.	16 55 W.	16	29 21	Zeitschrift, v. 6, p. 411
438	Teneriffe Is.	1400	28 12 N.	16 39 W.	4	48·3	Spanish Obs.
439	St. Helena Is.	1764	15 55 S.	5 43 W.	-----	17·77	Dove Beiträge, p. 94
440	Godthaab, Greenland	----	64 11 N.	51 46 W.	----	25 02	Danish Met. Obs.
441	Iviktut, Greenland	-- -	61 12 N.	48 11 W.	-----	49 37	Danish Met. Obs.
442	Ramah, Labrador	15	58 54 N.	62 59 W.	2	33·05	Canada Met. Obs.
443	York Factory, Hud. B.	55	57 0 N.	92 26 W.	3	29 8	Canada Met. Obs.
444	St. Paul Is., Bering Sea	50	57 7 N.	170 18 W.	5	35·00	Pacific C. Pilot, p. 26
445	Moose Factory, Canada	30	51 16 N.	80 56 W.	2	29·30	Canada Met. Obs.
446	Poplar Heights, Canada	----	50 5 N.	97 50 W.	1	26·3	Canada Met. Obs.
447	Gimli, Canada	723	50 37 N.	96 58 W.	1	26·75	Canada Met. Obs.
448	Quebec, Canada	----	46 48 N.	71 12 W.	6	37·27	Am. J. Sci., v. 12, p. 13
449	Montreal, Canada	----	45 30 N.	73 36 W.	9	41·76	Schott's Tables
450	Marquette, Michigan	----	46 32 N.	87 23 W.	12	33·48	Schott's Tables
451	Duluth, Wisconsin	----	46 48 N.	92 8 W.	8	25·64	Schott's Tables

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
452	St. Paul, Min.	----	44 55 N.	93° 5′ W.	5	25·09	Schott's Tables
453	Toronto, Canada	342	43 39 N.	79 23 W.	25	35·17	Schott's Tables
454	Oswego, N. Y.	250	43 28 N.	76 34 W.	8	46·94	Schott's Tables
455	Portland, Me.	187	43 38 N.	70 15 W.	4	48·63	Schott's Tables
456	Boston, Mass.	82	42 22 N.	71 4 W.	32	41·44	Schott's Tables
457	New York City	---	40 42 N.	74 0 W.	24	43·24	Schott's Tables
458	Detroit, Mich.	597	42 24 N.	82 58 W.	29	35·23	Schott's Tables
459	Chicago, Ill.	----	41 52 N.	87 35 W.	8	34·74	Sig. Service Obs.
460	Omaha, Neb	----	41 16 N	96 0 W.	2	35·02	Schott's Tables
461	Pittsburgh, Pa.	----	40 32 N.	80 2 W.	11	36·64	Schott's Tables
462	Washington, D. C.	110	38 53 N.	77 1 W.	19	37·96	Schott's Tables
463	Cincinnati, Ohio	----	39 6 N.	84 26 W.	30	44·50	Schott's Tables
464	St. Louis, Mo.	----	38 37 N.	90 15 W.	28	42·18	Schott's Tables
465	Louisville, Ky.	450	38 18 N.	85 52 W.	3	48·12	Schott's Tables
466	Norfolk, Va.	----	36 51 N.	76 19 W.	19	47·04	Schott's Tables
467	Chapel Hill, N. C.	----	35 54 N.	79 17 W.	4	42·71	Schott's Tables
468	Knoxville, Tenn.	1000	35 59 N.	83 54 W.	2	39·76	Schott's Tables
469	Memphis, Tenn.	262	35 8 N.	90 0 W.	9	44·25	Schott's Tables
470	Ft. Gibson, Ind. Ter.	560	35 48 N.	95 7 W.	20	36·37	Schott's Tables
471	Charleston, S. C.	25	32 47 N.	79 56 W.	41	43·51	Schott's Tables
472	Athens, Ga.	870	33 57 N.	83 25 W.	4	36·54	Schott's Tables
473	Vicksburgh, Mis.	350	32 23 N.	90 56 W.	15	48·87	Schott's Tables
474	San Antonio, Tex.	600	29 25 N.	98 25 W.	6	32·93	Schott's Tables
475	Portland, Or.	----	45 30 N.	122 27 W.	3	47·61	Schott's Tables
476	Ft. Humboldt, Cal.	50	40 45 N.	124 10 W.	11	35 92	Schott's Tables
477	Matamoras, Mex.	55	25 52 N.	97 27 W.	6	36·74	Schott's Tables
478	Chihuahua, Mex.	4610	28 38 N.	106 30 W.	3	25·44	Schott's Tables
479	Mazatlan, Mex.	249	23 11 N.	106 0 W.	1	33 64	International Obs.
480	Zacatecas, Mex.	8187	22 14 N.	102 33 W.	1	30·48	Bol. Geog., v. 5, p. 181
481	Lagos, Mex.	6339	21 25 N.	101 40 W.	1	34·12	Bol. Geog., v. 5, p. 181
482	Leon, Mex.	5901	21 6 N.	101 30 W.	1	27·92	Bol. Geog., v. 5, p. 181
483	Patzcuaro, Mex.	7015	19 31 N.	101 31 W.	1	43·72	Bol. Geog., v. 5, p. 181
484	Puebla, Mex.	7112	19 3 N.	98 11 W.	1	36·69	Bol. Geog., v. 5, p. 181
485	Oaxaca, Mex.	5072	17 3 N.	96 40 W.	1	37·44	Bol. Geog., v. 5, p. 181
486	Guadalajara, Mex.	----	21 5 N.	103 4 W.	6	32·90	Revista Clim., v.1, p.115
487	Tepic, Mex.	3458	21 22 N.	104 52 W.	7	42·9	Haughton's Ph. Geog.
488	Nassau, N. Prov.	80	25 5 N.	77 21 W.	3	46·75	Schott's Tables
489	St. Thomas, W. I.	---	18 21 N.	64 56 W.	3	35·19	Schott's Tables
490	Content, Jamaica	500	18 21 N.	77 45 W.	2	45·12	Q.J. Met.Soc., v. 4, p. 16
491	Falmouth, Jamaica	----	18 22 N.	77 40 W.	2	35·68	Q.J. Met. Soc., v. 4, p. 16
492	Dawkin's, Jamaica	60	18 3 N.	76 54 W.	4	37·58	Q.J. Met.Soc., v. 4. p. 16
493	Taylor's, Jamaica	60	18 3 N.	76 55 W.	6	44·25	Q.J. Met.Soc., v. 4, p. 16
494	Monaltrie, Jamaica	250	18 1 N.	76 50 W.	5	39·29	Q.J. Met.Soc., v. 4, p. 16
495	Park Camp, Jamaica	220	18 1 N.	76 47 W.	4	48·13	Q.J. Met.Soc., v. 4, p. 16
496	Kingston, Jamaica	40	17 58 N.	76 50 W.	7	39·85	Q.J. Met.Soc., v. 4, p. 16
497	Ashley Hall, Jamaica	75	17 56 N.	77 17 W.	5	43·83	Q.J. Met.Soc., v. 4. p. 16
498	Santa Cruz, W. I.	---	17 45 N.	64 50 W.	22	44·6	Zeitschrift, v. 12, p. 341
499	Antigua, W. I.	----	17 10 N.	61 48 W.	5	47·85	Dove Beiträge, p. 92
500	Curacao Is.	---	12 15 N.	69 20 W.	-----	26·64	Berghaus' Ph. Atlas
501	Bogota, N. Gren.	8958	4 40 N.	74 42 W.	6	43·8	Br. Met. Soc., v. 3, p.429
502	Salta, LaPlata	4920	24 51 S.	64 51 W.	5	44·98	Zeitschrift, v. 11, p. 137
503	Tucuman, LaPlata	1411	26 50 S.	65 10 W.	1	41·73	Zeitschrift, v. 11, p. 137
504	Cordoba, LaPlata	1240	31 0 S.	63 58 W.	3	30·51	Zeitschrift, v. 11, p. 137
505	Montevideo, LaPlata	46	34 54 S.	56 7 W.	10	43·56	Zeitschrift, v. 11, p. 137
506	Buenos Ayres, LaPlata	102	34 39 S.	58 28 W.	17	34·08	Clima de B. A.. p. 466
507	Tahiti, Soc. Is.	----	17 32 S.	149 34 W.	2	47·68	Zeitschrift, v. 4, p. 530

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
508	Turukansk, Siberia	....	65 45 N.	90 5 E.	1	16·4	Met. Annalen
509	Bogoslovsk, Ural Mt.	650	59 45 N.	59 59 E.	30	15·51	Repertorium für Met.
510	Enisseisk, Russia	265	58 27 N.	92 5 E.	7	14·8	Met. Annalen
511	Blagodat, Ural Mt.	1249	58 17 N.	59 47 E.	2	11·7	Met. Annalen
512	Tobolsk, Russia	355	58 12 N.	68 16 E.	7	17·82	Met. Annalen
513	Nijne Taguilsk, Ural M.	730	57 55 N.	59 53 E.	20	19·11	Repertorium für Met.
514	Irbit, Russia	....	57 41 N.	63 2 E.	6	19·60	Met. Annalen
515	Catherinbourg, Ural Mt.	850	56 48 N.	60 35 E.	31	13 36	Met. Annalen
516	Tomsk, Russia	241	56 30 N.	84 58 E.	4	14·4	Met. Annalen
517	Ischim, Russia	....	56 6 N.	69 27 E.	6½	16·67	Repertorium für Met.
518	Zlatouste, Ural Mt.	1230	55 11 N.	59 45 E.	31	18·11	Repertorium für Met.
519	Omsk, Russia	261	54 58 N.	73 20 E.	2	13·00	Met. Annalen
520	Isalair, Russia	1125	54 15 N.	85 47 E.	4	13·0	Met. Annalen
521	Nikolaiwsk, China	82	53 18 N.	140 45 E.	6	16·3	Met. Annalen
522	Irkutzk, Russia	1514	52 17 N.	104 22 E.	5	17·5	Met. Annalen
523	Orenbourg, Russia	220	51 45 N.	59 6 E.	25	17·67	Met. Annalen
524	Nertschinsk, Russia	2230	51 18 N.	119 36 E.	27	15·38	Met. Annalen
525	Blagoweststhuck, China	....	50 15 N.	127 38 E.	1	13·2	Met. Annalen
526	Chabarawka, China	....	48 28 N.	135 7 E.	1	14·5	Met. Annalen
527	Urga, Mongolia	....	47 55 N.	108 50 E.	2	12·4	Met Annalen
528	Vladivostok, China	86	43 7 N.	131 54 E.	4	13·8	Met. Annalen
529	Taschkent, Tartary	1588	41 20 N.	69 18 E.	5	13·3	Met. Annalen
530	Pekin, China	100	39 53 N.	116 40 E.	22	24·9	Met. Annalen
531	Tientsin, China	....	39 7 N.	117 10 E.	1	19·4	Met. Annalen
532	Shien Sheen, China	....	38 17 N.	117 10 E.	4	21·73	Boll. Mens., v. 1. p. 101
533	Bannu, Punjab	....	33 1 N.	70 40 E.	16–17	13·60	India, 1878. p. 111
534	Shakpur, Punjab	....	32 20 N.	72 24 E.	24–25	14·99	India, 1878, p. 111
535	Jhang, Punjab	....	31 16 N.	72 19 E.	16–17	12·10	India, 1878. p. 111
536	Montgomery, Punjab	....	30 45 N.	73 11 E.	18–19	10·45	India, 1878, p. 111
537	Jodhpore, Rajputana	....	26 15 N.	73 5 E.	5	13·87	India, 1878. p. 111
538	Umarkot, Bombay	...	25 20 N.	69 42 E.	10–14	11·75	India, 1878, p. 111
539	Erinpoora, Rajputana	...	25 13 N.	7 6 E.	11	13·61	India, 1878, p. 111
540	Pitea, Sweden	....	65 19 N.	21 31 E.	.....	16·22	Koner, v. 13. p. 106
541	Hernosand, Sweden	....	62 35 N.	17 53 E.	.....	21·15	Koner, v. 13. p. 106
542	Abo, Russia	....	60 27 N.	22 17 E.	48	23·57	Repertorium für Met.
543	St. Petersburg, Russia	10	59 56 N.	30 18 E.	31	17·67	Repertorium für Met.
544	Stockholm, Sweden	....	59 22 N.	18 0 E.	....	15·79	Koner, v. 13. p. 106
545	Kostroma, Russia	....	57 45 N.	40 56 E.	11	19·11	Repertorium für Met.
546	Kalmar, Sweden	....	56 37 N.	16 20 E.	.....	12·76	Koner, v. 13. p. 106
547	Libau, Russia	....	56 30 N.	21 1 E.	5	22·85	Repertorium für Met.
548	Kasan, Russia	280	55 47 N.	49 7 E.	16	13·94	Repertorium für Met.
549	York, England	....	53 58 N.	1 5 W.	....	24·06	Koner, v. 13. p. 106
550	Samara, Russia	....	53 10 N	50 2 E.	10	15·09	Repertorium für Met.
551	Berlin, Prussia	....	52 31 N.	13 21 E.	.....	23·51	Koner, v. 13. p. 108
552	Warsaw, Russia	430	52 13 N.	21 1 E.	33	22·70	Repertorium für Met.
553	Koursk, Russia	700	51 44 N.	36 14 E.	18	16·81	Repertorium für Met.
554	London, England	....	51 30 N.	0 0	.....	24 57	Koner, v. 13. p. 106
555	Bonn, Germany	....	50 42 N.	7 3 E.	.....	23·43	Koner, v. 13. p. 106
556	Prag, Austria	....	50 6 N.	14 23 E.	.....	15·35	Koner, v. 13. p. 106
557	Paris, France	....	48 50. N.	2 20 E.	.....	20·08	Koner, v. 13, p. 106
558	Vienna, Austria	....	48 12 N.	16 20 E.	.....	19·33	Koner, v. 13. p. 106
559	Odessa, Russia	147	46 25 N.	30 44 E.	13	13·08	Repertorium für Met.
560	Toulouse, France	....	43 35 N.	1 26 E.	.....	23·62	Koner, v. 13. p. 106
561	Tiflis, Caucasus	1500	41 41 N.	44 50 E.	24	19·26	Repertorium für Met.
562	Baku, Caucasus	53	40 42 N.	48 53 E.	17	10·06	Repertorium für Met.
563	Palermo, Sicily	....	38 7 N.	13 19 E.	.....	23·58	Koner, v. 13. p. 107
564	Ooromiah, Persia	7334	37 28 N.	45 8 E.	1	21·51	Am. J. Sci., v. 20. p. 256

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
565	Valladolid, Spain	1680	41 39 N	° ′ 4 43 W.	10	11·97	Anuario del Obs., 1879
566	Albacete, Spain	2251	39 0 N.	1 51 W.	9	13·15	Anuario del Obs., 1879
567	Ciud Real, Spain	2246	38 59 N.	3 55 W.	9	12·44	Anuario del Obs., 1879
568	Sevilla, Spain	98	37 22 N.	6 0 W.	10	12·01	Anuario del Obs, 1879
569	Oran, North Africa	164	35 41 N.	0 39 W.	27	20·60	An. Met. de France
570	Jerusalem, Palestine	2500	31 46 N.	35 13 E.	5	18·83	J. Met. Soc., Oct. 1867
571	Goree, Senegal	----	14 40 N.	17 31 W.	8	21·0	Haughton, Ph. Geog.
572	St. Louis, Senegal	----	15 33 N.	16 30 W.	7	16·06	Zeitschrift, v. 8, p. 348
573	Christiansborg, W. Af.	45	5 35 N.	0 16 W.	9	22·71	Obs. Met., 1829–42
574	St. Paul de Loanda, W. A.	----	8 48 S.	13 13 E.	-----	13·5	Johnston's Af., p. 582
575	O'Halloran Hill S. Aust.	----	27 28 S.	135 30 E.	10	23·50	Zeitschrift, v. 9, p. 202
576	Aliwal, S. Africa	4400	30 43 S.	25 40 E.	14	22·86	Q. J. Met. Soc., v. 7, p. 5
577	Brakfontein, S. Africa	4000	31 40 S.	23 10 E.	7	10·67	Q. J. Met. Soc., v. 7, p. 5
578	Lower Nel's Poort, S. A.	3000	32 14 S.	23 4 E.	6	10·06	Q. J. Met. Soc., v. 7, p. 5
579	Worcester, S. Africa	780	33 40 S.	19 27 E.	13	14·29	Q. J. Met. Soc., v. 7, p. 5
580	Port Elizabeth, S. Af.	180	33 57 S.	25 37 E.	13	24·36	Q. J. Met. Soc., v. 7, p. 5
581	Mossel Bay, S. Africa	100	34 11 S.	22 10 E.	6	16·72	Q. J. Met. Soc., v. 7, p. 5
582	Kooringa, S. Aust.	----	33 42 S.	138 59 E.	11	18·19	Zeitschrift, v. 9, p. 202
583	Kapunda, S. Aust.	----	34 20 S.	139 0 E.	9	18·70	Zeitschrift, v. 9, p. 202
584	Adelaide, S. Aust.	----	34 40 S.	138 46 E.	34	21·38	Zeitschrift, v. 9, p. 202
585	Strathalbyn, S. Aust.	----	35 8 S.	138 57 E.	-----	17·84	Zeitschrift, v. 9, p. 202
586	Fehuca, Victoria	280	36 6 S.	144 48 E.	2	15·95	Zeitschrift, v. 7, p. 293
587	Longerenong, Victoria	464	36 12 S.	142 30 E.	3	17·80	Zeitschrift, v. 7, p. 293
588	Sandhurst, Victoria	779	36 48 S.	144 6 E.	6	24·06	Zeitschrift, v. 7, p. 293
589	Heatheote, Victoria	789	36 54 S.	144 42 E.	6	23·14	Zeitschrift, v. 7, p. 293
590	Castlemain, Victoria	942	37 6 S	144 18 E.	3	21·22	Zeitschrift, v. 7, p. 293
591	Geelong, Victoria	96	38 12 S.	144 24 E.	3	20·95	Zeitschrift, v. 7, p. 293
592	Goose Island	26	40 18 S.	147 45 E.	5	20·95	Zeitschrift, v. 7, p. 394
593	Swan's Island	106	40 44 S.	148 10 E.	5	22·64	Zeitschrift, v. 7, p. 394
594	Hobarttown, Tasmania	37	42 52 S.	147 21 E.	30	23·05	Zeitschrift, v. 7, p. 394
595	Grimsey, Iceland	----	66 34 N.	18 3 W.	-----	19·87	Danish Met. Obs.
596	Upernivik, Greenland	---	72 47 N.	56 0 W.	-----	11·74	Danish Met. Obs.
597	Kornok, Greenland	---	64 30 N.	51 10 W.	-----	13·02	Danish Met. Obs.
598	St. Michael's, Alaska	30	63 28 N.	161 48 W.	3	11·30	Pacific C. Pilot, p. 26
599	Clinton, Canada	2978	51 6 N.	121 48 W.	1	11·6	Canada Met. Obs.
600	Lilooet, Canada	----	50 42 N.	122 2 W.	2	11·5	Canada Met. Obs.
601	Kamloops, Canada	1150	50 41 N.	120 28 W.	1	12·0	Canada Met. Obs.
602	Spence's Bridge, Can.	760	50 25 N.	121 30 W.	3	10·1	Canada Met. Obs.
603	O. Kanagan, Canada	----	50 23 N.	119 27 W.	1	13·2	Canada Met. Obs.
604	Nicola Lake, Canada	2100	50 16 N.	120 43 W.	2	10·3	Canada Met. Obs.
605	Lytton, Canada	500	50 14 N.	121 37 W.	1	17·2	Canada Met. Obs.
606	Lit. Britain, Canada	----	50 6 N.	96 57 W.	1	18·2	Canada Met. Obs.
607	Rockwood, Canada	----	50 5 N.	97 12 W.	1	20·04	Canada Met. Obs.
608	Winnipeg, Canada	746	49 55 N.	97 7 W.	4	20·1	Canada Met. Obs.
609	Anticosti I., Canada	20	49 24 N.	63 36 W.	4	21·6	Canada Met. Obs.
610	Ft. Lapway, Idaho	----	46 18 N.	116 54 W.	3	17·00	Schott's Tables
611	Ft. Abercrombie, Dak.	----	46 27 N.	96 28 W.	7	17·34	Schott's Tables
612	Ft. Mackinaw, Mich.	728	45 51 N.	84 33 W.	13	23·96	Schott's Tables
613	Ft. Dalles, Oregon	350	45 36 N.	120 55 W.	12	21·74	Schott's Tables
614	Ft. Randall, Dakota	1245	43 1 N.	98 12 W.	9	16 51	Schott's Tables
615	Ft. Laramie, Wyom. T.	4519	42 12 N.	104 31 W.	12	15·16	Schott's Tables
616	Ft. Crook, Cal.	3390	41 6 N.	121 25 W.	8	23·68	Schott's Tables
617	Salt Lake City, Utah	4320	40 46 N.	112 6 W.	6	23·85	Schott's Tables
618	Ft. Riley, Kansas	1300	39 3 N.	96 35 W.	14	23·62	Schott's Tables
619	Sacramento, Cal.	82	38 34 N.	121 28 W.	18	19·56	Schott's Tables
620	San Francisco, Cal.	140	37 48 N.	122 27 W.	13	20·17	Schott's Tables
621	Ft. Massachusetts, Col.	8365	37 32 N.	105 23 W.	5	17·06	Schott's Tables

Mean Annual Rain-fall for various stations—Continued.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
622	Ft. Marcy, N. Mexico	6846	35 41 N.	106 2 W.	12	16·65	Schott's Tables
623	Ft. Craig, N. Mexico	4576	33 26 N.	107 8 W.	9	11·67	Schott's Tables
624	Ft. Thorn, N. Mexico	4500	32 47 N.	107 21 W.	5	14·63	Schott's Tables
625	Ft. Davis, Texas	4700	30 26 N.	103 37 W.	6	18·71	Schott's Tables
626	Ft. Clark, Texas	1000	29 17 N.	100 25 W.	8	22·38	Schott's Tables
627	Ft. Duncan, Texas	1460	28 42 N.	100 30 W.	10	21·23	Schott's Tables
628	Ft. McIntosh, Texas	806	27 30 N.	99 29 W.	9	17·84	Schott's Tables
629	Ringgold Barracks, Tex.	521	26 23 N.	98 47 W.	10	21·32	Schott's Tables
630	Sombrero, W. I.	45	18 37 N	63 27 W.	2	16·84	Schott's Tables
631	San Louis Potosi, Mex.	6202	22 9 N.	100 58 W.	1	15·7	Boletin de Geog., v. 5
632	Pabellon, Mexico	6314	22 4 N.	102 11 W.	1	17·1	Boletin de Geog., v. 5
633	Honolulu, Sand. Is.	----	21 16 N.	157 59 W.	-----	22·0	Guyot's Ph. Geog.
634	Mexico City	7474	19 25 N.	99 5 W.	14	24·7	Haughton, Ph. Geog.
635	Valparaiso, Chili	151	33 6 S.	71 40 W.	5	13·50	Zeitschrift, v. 11, p. 137
636	Santiago, Chili	1919	33 28 S.	70 48 W.	19	14·10	Zeitschrift, v. 11, p. 137
637	Talca, Chili	344	35 26 S.	71 0 W.	4	19·87	Zeitschrift, v. 11, p. 137
638	Bahia Blanca, LaPlata	62	38 42 S.	61 45 W.	15	17·72	Zeitschrift, v. 11, p. 137
639	Falkland Is.	----	51 41 S.	57 51 W.	3	20·33	Q.J. Met Soc., Oct., 1850
640	Punta Arenas	33	53 12 S.	71 0 W.	8	22·55	Zeitschrift, v. 11, p. 137
641	Yakutsk, Siberia	299	62 2 N.	129 45 E.	-----	9·	Guyot's Ph. Geog.
642	Okhotsk, Siberia	12	59 20 N.	142 40 E.	3	4·53	Pacific O. Pilot, p. 26
643	Barnaoul, Russia	400	53 20 N.	83 57 E.	30	9·05	Repertorium für Met.
644	Akmolinsk, Russia	843	51 12 N.	71 23 E.	5	9·2	Met. Annalen
645	Ssemipalatinsk, Russia	598	50 24 N.	80 13 E.	4	7·7	Met. Annalen
646	Kjachta, Russia	2525	50 20 N.	106 35 E.	2	8·9	Met. Annalen
647	Irgis, Tartary	367	48 37 N.	61 16 E.	9	6·3	Met. Annalen
648	Astrakhan, Russia	55	46 21 N.	48 5 E.	7	4·89	Repertorium für Met.
649	Raimsk, Russia	----	46 4 N.	61 47 E.	1½	5·99	Dove Beiträge, p. 183
650	Fort No. 1, Russia	149	45 46 N.	62 7 E.	4	3·5	Met. Annalen
651	Sevastopol, Russia	160	44 36 N.	33 31 E.	16	9·05	Repertorium für Met.
652	Novo Petrowsk, Russia	100	44 27 N.	50 8 E.	8	5·03	Repertorium für Met.
653	Nakust, Russia	216	42 27 N.	59 37 E.	4	3·1	Met. Annalen
654	Petro Alexandrovsk	326	41 28 N.	61 5 E.	4	2·8	Met. Annalen
655	Aralych, Russia	2600	39 53 N.	44 31 E.	4	6·04	Repertorium für Met.
656	Leh, Kashmir	11538	34 10 N.	77 42 E.	3	1·32	India, 1878, p. 111
657	Dera Ismail Khan	572	32 0 N.	71 5 E.	16–17	9·28	India, 1878, p. 111
658	Multan, Punjab	420	31 10 N.	71 33 E.	21	7·52	India, 1878, p. 111
659	Dera Ghazi Khan	----	30 5 N.	70 49 E.	16–17	7·39	India, 1878, p. 111
660	Muzaffargarh	----	30 4 N.	71 16 E.	18–19	6·36	India, 1878, p. 111
661	Jacobabad, Bombay	185	28 24 N.	68 18 E.	18	4·86	India, 1878, p. 118
662	Shikarpore, Bombay	----	28 0 N.	68 39 E.	14–16	5·43	India, 1878, p. 118
663	Rohri, Bombay	----	27 38 N.	68 55 E.	17–18	6·35	India, 1878, p. 118
664	Sehwan, Bombay	----	26 31 N.	67 48 E.	13–14	8·50	India, 1878, p. 118
665	Hyderabad, Bombay	134	25 25 N.	68 27 E.	12–16	8·28	India, 1878, p. 118
666	Kurrachee, Bombay	49	24 47 N.	67 4 E.	22–23	7·61	India, 1878, p. 118
667	Tatta, Bombay	----	24 46 N.	68 0 E.	10	9·00	India, 1878, p. 118
668	Biscara, Algeria	350	34 51 N.	5 40 E.	-----	8·58	Koner, v. 13, p. 107
669	Bagdad, Turkey	----	33 21 N.	44 22 E.	-----	6·0	Koner, v. 13, p. 107
670	Alexandria, Egypt	623	31 12 N.	29 52 E.	10	8·46	Zeitschrift, v. 12, p. 634
671	Cairo, Egypt	----	30 2 N.	31 15 E.	----	1·31	Arago Melanges, p. 463
672	Keneh, Egypt	----	26 39 N.	32 45 E.	-----	0	Johnston's Af., p. 563
673	Mourzouk, Fezzan	----	25 54 N.	14 12 E.	----	0	Gehler, v. 7, p. 1251
674	Thebes, Egypt	----	25 43 N.	32 35 E.	-----	0	Wilkinson's Egypt, v. 4
675	Kotree, Sind	----	25 20 N.	68 14 E.	-----	0	Phil Trans., 1850, p. 361
676	Stuart's Creek, S. Aust.	----	29 44 S.	138 23 E.	1	9·70	Todd's Met. Obs., p. 126
677	Arrowie, S. Aust.	----	30 51 S.	139 55 E.	1	8·99	Todd's Met. Obs., p. 126

Mean Annual Rain-fall for various stations—Concluded.

No.	Station.	Elev. Feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
678	Angoriehina, S. Aust.	....	31 ' S.	139 ' E.	5	8·70	Zeitschrift, v. 9, p. 202
679	Wirrialpa, S. Aust.	....	31 0 S.	139 45 E.	1	9·63	Todd's Met. Obs., p. 126
680	Eucla, S. Aust.	7	31 45 S.	128 59 E.	1	6·37	Todd's Met. Obs., p. 126
681	Kanjaka, S. Aust.	....	32 10 S.	138 25 E.	4	9·65	Zeitschrift, v. 9, p. 202
682	Port Augusta, S. Aust.	....	32 29 S.	137 45 E.	19	8·60	Todd's Met. Obs., p. 126
683	Moorna, N. S. Wales	....	34 5 S.	141 30 E.	1	6·93	Todd's Met. Obs., p. 126
684	Wentworth, N.S. Wales	....	34 5 S.	141 42 E.	1	9·43	Todd's Met. Obs., p. 126
685	Salamanca, Spain	....	41 13 N.	5 43 W.	.....	9·45	Koner, v. 13, p. 107
686	Mascara, Algeria	....	34 40 N.	0 20 W.	1	8·5	An Met. de France.
687	Tafilet, Algeria	....	30 50 N.	3 39 W.	.....	0	Johnston's Af., p. 562
688	Tatta, North Africa	....	28 39 N.	6 46 W.	.....	0	Gehler, v. 7. p. 1251
689	Ascension Is.	....	7 55 S.	14 28 W.	2	3·3	Charts of Met. Data
690	Jacobshavn, Greenland	....	69 13 N.	50 55 W.	.....	8·42	Danish Obs.
691	Fort Rae, Canada	....	62 40 N.	115 10 W.	1	6·05	Can. Met. Obs., 1875
692	Ft. Colville, Wash. T.	....	48 42 N.	118 2 W.	4	9·83	Schott's Tables
693	Ft. Bridger, Utah	6656	41 20 N.	110 23 W.	6	6·12	Schott's Tables
694	Camp Floyd, Utah	4860	40 13 N.	112 8 W.	2½	7·34	Schott's Tables
695	Ft. Churchill, Nev.	4284	39 17 N.	119 19 W.	2½	5·67	Schott's Tables
696	Ft. Garland, Col.	8365	37 32 N.	105 40 W.	6	6·11	Schott's Tables
697	Tonaquint, Utah	....	37 11 N.	113 50 W.	2½	8·38	Schott's Tables
698	Camp Burgwin, N. Mex.	....	36 26 N.	105 26 W.	6	8 65	Schott's Tables
699	Albuquerque, N. Mex.	5032	35 6 N.	106 38 W.	12	8·12	Schott's Tables
700	Ft. Mojave, Arizona	604	35 6 N.	114 35 W.	2	2·51	Schott's Tables
701	Socorro, N. Mex.	4560	34 10 N.	106 50 W.	2	7·86	Schott's Tables
702	Ft. Conrad, N. Mex.	4576	33 34 N.	107 9 W.	4	6·76	Schott's Tables
703	Ft. Yuma, Cal.	200	32 44 N.	114 36 W.	10	3·46	Schott's Tables
704	Ft. San Diego, Cal.	150	32 42 N.	117 14 W.	13	9·16	Schott's Tables
705	Ft Fillmore, N. Mex.	3937	32 14 N.	106 15 W.	8	8·42	Schott's Tables
706	Ft. Bliss, Texas	3830	31 47 N.	106 30 W.	8	9·56	Schott's Tables
707	Ft. Quitman, Texas	3710	30 40 N.	105 0 W.	2	6·26	Schott's Tables
708	Cumana	....	10 27 N.	64 15 W.	.....	7·52	Gehler, v. 7. p. 1311
709	Lima, Peru	530	12 0 S.	77 2 W.	.....	0	Arago's Met. Essays
710	Atacama	....	22 36 S.	68 40 W.	.....	0	Mühry Uebersicht.p.28
711	Copiapo, Chili	82	27 38 S.	70 38 W.	4	0·32	Zeitschrift. v. 11, p. 137
712	La Serena, Chili	82	29 56 S.	71 16 W.	4	0·51	Zeitschrift. v. 11, p. 137
713	Mendosa, La Plata	2559	33 0 S.	69 24 W.	4	6·97	Zeitschrift. v. 11, p. 137

The first column in the table contains the reference number; column second gives the name of the station; column third gives its elevation above the sea expressed in English feet. For many stations the elevation is not given, and where the figure 0 is inserted it is to be understood as signifying that the station is but little elevated above sea-level. Columns four and five give the latitude and longitude of the station from Greenwich; column sixth shows the number of years of observation represented; column seventh shows the mean annual rain-fall expressed in English inches; and column eighth gives the authority for the results. In the last column, India, 1878, stands for Blanford's Report on the Meteorology of India in 1878; Bergsma, 1879, stands for Bergsma's Report on the rain-fall in the East Indian Archipelago for 1879; Haughton Ph. Geog., stands for Haughton's Lectures on Physical Geography;

Koner, stands for Koner's Zeitschrift der Gesellschaft für Erdkunde zu Berlin; Q. J. Met. Soc., stands for Quarterly Journal of the London Meteorological Society; Zeitschrift, stands for Zeitschrift der österreichischen Gesellschaft für Meteorologie; An. Met. de France, stands for Annuaire Meteorologique de la France; Dove Beiträge, stands for Klimatologische Beiträge von H. W. Dove, 1857; Schott's tables, stands for Tables of the precipitation in rain and snow in the United States, by Charles A. Schott, 1872; Repertorium für Met., stands for Repertorium für Meteorologie, Band I., redijirt von Dr. Heinrich Wild, St. Petersburg; Met. Annalen, stands for Annalen der Physikalischen central Observatoriums, St. Petersburg; Bol. Geog., stands for Boletin de la Sociedad de Geografia y Estadistica de la Republica Mexicana; Revista Clim., stands for Revista mensual Climatologica.

Cases of excessive rain-fall.

The rain-fall at Cherapunji (No. 1), is very much greater than at any other known station, and nearly all of this rain falls during the warmer months of the year. In the following table, column second shows the average rain-fall at Cherapunji for each month of the year; column third shows the average direction of the wind at Calcutta, and column fourth shows its average direction at Chittagong, situated at the head of the Bay of Bengal:

	Rain Cherapunji.	Winds Calcutta.	Winds Chittagong.		Rain Cherapunji.	Winds Calcutta.	Winds Chittagong.
Jan.	0·73	N. 38 W.	N. 26° W.	July	133·54	S. 11° E.	S. 42° E.
Feb.	2·76	S. 81 W.	N. 40 W.	Aug.	77·31	S. 17 E.	S. 31 E.
Mar.	7·05	S. 32 W.	S. 60 W.	Sept.	58·01	S. 27 E.	S. 27 E.
April	30·63	S. 3 W.	S. 13 W.	Oct.	14·02	N. 48 W.	N. 19 W.
May	51·09	S. 11 E.	S. 7 W.	Nov.	2·50	N. 17 W.	N. 19 W.
June	114·70	S. 4 E.	S. 30 E.	Dec.	0·11	N. 26 W.	N. 24 W.

Thus we see that ninety-five per cent of the annual rain at Cherapunji falls during the six months from April to September, inclusive; and during these months the average wind at Calcutta and Chittagong is from the south, while during most of the other six months of the year the average wind is from the northwest.

Cherapunji is situated on the Khasi Hills, 200 miles north of Chittagong, and at an elevation of 4125 feet above the sea. When the wind in the Bay of Bengal blows from the south, rain falls almost incessantly on the Khasi Hills; and when the wind changes to the west or northwest, the rain ceases almost entirely. These facts indicate that the rain-fall is due to an upward deflection of the winds as they encounter a range of

mountains, and the precipitation of the vapor is due not to any special coldness of the mountain, but to the cold of elevation; and the extraordinary amount of the rain-fall is due to an unusual combination of circumstances, viz: 1. The high temperature of the air. (During the months, April to September, the mean temperature of the air at Calcutta is 84°·4 F., and at Chittagong, 81°·9.) 2. Its great humidity coming directly from the Indian Ocean. (During the months, April to September, the average relative humidity of the air at Chittagong is 84.) 3. The proximity of the mountains to the ocean and the abruptness of their elevation.

At stations 2 and 3 the rain fall occurs with the same system of winds as at No. 1.

Nos. 4–7 are situated on the west coast of Hindostan, on the range of mountains parallel with the coast, and 98 per cent of all the rain at these stations falls during the five months from June to September, inclusive, during the prevalence of the southwest monsoon.

Nos. 8 to 10 are situated on the island of Java, and the rain is distributed pretty uniformly through the different months of the year. A chain of mountains extends through the center of this island from west to east, with peaks varying in height from 4,000 to 12,000 feet. No. 11 is on the west coast of the island of Sumatra. This island has mountains rising to the height of 14,000 or 15,000 feet. No. 12 is also situated on a mountainous island. The last five stations during half of the year are within the limits of the southeast trade winds, but during the remainder of the year the winds blow from the west or southwest. No. 13 is situated on an island with mountains over 5,000 feet high, and abundant rains occur in all months of the year. No. 14 is near the belt of calms which separate the northeast from the southeast trade winds.

If we institute a similar comparison of the subsequent cases in the table as far as No. 204 we shall find that they may be classified as follows:

1. Stations on the north and east of the Bay of Bengal, where the rain comes almost wholly with the southwest monsoon, viz: Nos. 1–3, 15–21, 42–54, 120–138.

2. Stations on the west and south part of Hindostan and Ceylon (including a few interior stations), where the rain is also confined almost entirely to the southwest monsoon, viz: Nos. 4–7, 22–26, 55–71, 139–148.

3. Islands situated within the tropics (including a few stations in China, Australia and New Zealand), generally having mountains rising to a height of several thousand feet, viz: Nos. 8–13, 27–35, 72–103, 149–183.

4. Stations on the eastern coast of the American continent,

chiefly within the limits of the trade winds, including a few mountain stations somewhat distant from the coast, viz: Nos. 14, 36–39, 104–110, 184–191.

5. Elevated stations in different parts of Europe including the northwest part of England, the west of Scotland, the coast of Portugal, Norway, etc., viz: Nos. 40 and 41, 111–113, 192–194.

6. Stations on the west coast of Africa, including one in the interior, viz: Nos. 114–116, 195 and 196.

7. Stations on the west coast of North America, viz: Nos. 117–119, 197–204.

The table shows 204 stations at which the mean annual rain-fall exceeds 75 English inches. We see that some of these stations are elevated more than 2,000 feet above the sea, and nearly all of them are situated within 100 or 200 miles of elevated mountains, and the rain chiefly occurs when the wind from the ocean is blowing toward these mountains. There appears no room for doubt that the extraordinary rain-fall at most of these stations is due to the influence of the mountains by which the wind is deflected upward to such a height that a considerable portion of the contained vapor is condensed by the cold of elevation.

Cases of deficient rain-fall.

Among the group of cases in the table having a mean annual rain-fall of less than 10 inches, the most remarkable example is No. 689. This station is on a small but mountainous island

Latitude.	Longitude from Greenwich.					
	40° to 35°.	35° to 30°.	30° to 25°.	25° to 20°.	20° to 15°.	15° to 10°.
20° to 18° N.	3	2	1	0	0	*
18 to 16	3	2	1	1	0	*
16 to 14	1	3	2	2	1	*
14 to 12	2	3	3	3	1	*
12 to 10	4	5	6	6	5	*
10 to 8	9	9	12	11	8	4
8 to 6	7	13	17	15	10	12
6 to 4	8	15	17	18	11	8
4 to 2 N.	6	10	15	15	11	4
2 to 0	3	11	7	9	7	2
0 to 2 S.	5	6	5	4	3	0
2 to 4	1	5	6	5	2	0
4 to 6	*	5	4	3	2	1
6 to 8	*	5	2	4	1	1
8 to 10 S.	*	5	3	1	2	1

situated in the middle of the Atlantic Ocean in latitude 7° 55′ S. In order to determine whether the small rain-fall at this station is due to local causes, I have prepared a table showing the distribution of rain in that part of the Atlantic Ocean situ-

ated between the meridians of 10 and 40 degrees west from Greenwich, and between the parallels of 20° N. lat. and 10° S. lat. This table is derived from a work entitled "Meteorological Data," published by authority of the Meteorological Committee of the Royal Society of London, and the figures represent the number of rains corresponding to a hundred observations of the wind reported in the log-books examined.

The stars in the table denote squares covered by land. From this table we see that a little north of the equator, there is a belt several degrees in breadth, within which there is a remarkable persistence of rainy days, and at a distance of a few degrees on each side of this belt, rain rarely occurs. The following table is constructed upon a plan similar to the preceding, and shows for each month of the year the average number of rains corresponding to a hundred wind observations between the meridians of 20° and 30° west from Greenwich.

Rains on the Atlantic Ocean from 20° to 30° West Longitude.

Latitude.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
20° to 18° N.	1	0	0	0	0	0	0	0	2	0	1	1
18 to 16	1	0	0	0	0	0	1	2	4	2	1	1
16 to 14	0	0	0	0	0	0	0	10	4	2	2	1
14 to 12	0	0	0	0	0	0	5	13	9	7	3	1
12 to 10	1	0	0	0	1	2	13	18	14	12	5	1
10 to 9	3	0	0	0	3	8	23	27	22	20	14	5
9 to 8	0	0	0	0	3	20	28	28	20	20	21	6
8 to 7	8	0	0	1	6	28	31	20	18	27	28	16
7 to 6	14	2	1	1	13	30	25	15	17	22	27	23
6 to 5	19	3	8	9	24	26	13	8	18	26	25	21
5 to 4	25	14	16	19	30	23	4	2	15	24	26	18
4 to 3	32	23	19	25	26	18	6	1	8	16	16	16
3 to 2	22	26	26	23	20	8	1	1	2	6	8	6
2 to 1 N.	25	23	18	19	13	2	2	1	0	3	4	5
1 to 0	19	14	12	17	9	0	0	0	0	1	3	6
0 to 2 S.	5	8	10	12	9	1	1	0	0	1	2	2
2 to 4	4	7	10	13	10	5	3	2	0	2	2	2
4 to 6	3	2	6	6	3	5	4	1	2	2	1	0
6 to 8	1	4	8	6	4	2	3	0	4	2	0	0
8 to 10 S.	1	1	0	0	4	4	0	2	6	1	0	0

We see from this table that the center of the belt of rain oscillates from about 2° N. latitude near the close of winter, to 9° N. latitude near the close of summer, and the belt is 6° or 7° in breadth. This belt corresponds to the region of calms between the N.E. and S.E. trade winds where the upward movement of these winds takes place. From these tables, combined with the information derived from Maury's Pilot Charts and from other sources, we learn that in mid-ocean, between the N. E and S.E. trade winds there is a belt of calms where the rainfall is excessive, but that within the limits of the trade winds, as long as these winds maintain their usual course, rain is of

rare occurrence. Beyond the limits of the trade winds, rains increase in frequency; and in the Atlantic Ocean beyond latitude 45° N. or 40° S. they are as frequent as within the belt of equatorial calms. This statement explains the small rain-fall at the island of Ascension, which lies within the S.E. trades, and we see that a small rain-fall does not prove that the air of the place is dry, but simply that there is no cause sufficient to produce a strong upward movement of the atmosphere. The principle here developed is the most important one which affects the amount of rain-fall at different places, viz: that excessive rain-fall results from an unusually strong and persistent upward motion of the atmosphere, while a deficient rain-fall results mainly from the absence of this upward motion. The atmosphere always contains vapor, even in the midst of deserts, and during periods of unusual drouth, and a strong upward movement of the dryest atmosphere would precipitate a portion of its vapor in the form of rain or snow. This principle affords (in part but not wholly) the explanation of the rainless regions of the globe.

Another cause of deficient rain-fall which is frequently exemplified is this: if by the interposition of a chain of elevated mountains a current of air is forced upward to a great height and its vapor is condensed, when the air subsequently descends upon the other side of the mountain and comes under greater pressure, its temperature is raised and the air becomes very dry. Such an effect is produced by the chain of the Rocky Mountains, as I have shown in my 13th paper. A similar effect is observed wherever there is an extensive movement of the atmosphere over a long chain of elevated mountains. These principles will assist in explaining most of the rain-less districts of the globe. The Great Desert which stretches from the Atlantic Ocean across Northern Africa and Southern Asia to the Indus, is situated within the N.E. trade winds, within which, as we have seen, very little rain falls in the midst of the Atlantic Ocean. The principal rain-belt of Africa corresponds pretty nearly with the rain-belt which we have found on the Atlantic Ocean a little north of the equator, but its latitude is somewhat affected by the position of the ranges of mountains. The Great Desert of Gobi is in part caused by the drying effect of the Himalaya Mountains upon the southwest winds which have traversed them. It is believed however to be due in part to the operation of another principle which may be stated as follows: In order that a strong upward movement of the atmosphere may prevail over any district, it is necessary that the neighboring air should flow freely toward this district. Whatever impedes the flow of air from neighboring regions must obstruct the upward movement at the point first supposed.

Such an effect may be produced by an obstructing range of mountains, and if a district is completely surrounded by ranges of mountains, any strong upward movement of the air over this district seems impossible, unless from currents of air prevailing at an elevation greater than the summits of the surrounding mountains. Spain affords a remarkable example of the operation of this principle. This country is divided by numerous chains of mountains, one of which upon the north and northwest sides condenses the vapor coming in from the ocean, and presents a continuous belt of excessive rain-fall. But between the different ranges of mountains which traverse this country are small table lands almost entirely surrounded by mountain ranges, and these regions are marked by a great deficiency of rain. One of these is in the neighborhood of Salamanca, where the mean rainfall is only 9·45 inches, although at Santiago, distant less than 200 miles, the average annual rain-fall amounts to 67·60 inches. The extreme dryness at Salamanca does not seem to be due entirely to the great rain-fall upon the mountains situated on the western coast, because in many other parts of Europe (e. g. the coast of Norway) a similar rain-fall upon a range of mountains is not accompanied by an equal dryness upon the eastern side of the mountains. The dryness which prevails over the desert of Gobi is doubtless due in a great measure to the extreme precipitation upon the elevated mountains on the southwest, but this effect is aggravated by the influence of the other mountain ranges by which Gobi is almost entirely surrounded. The small rain-fall which prevails on the east side of the Caspian Sea, is in part due to the influence of the Caucasus and other mountains on the southwest; but this effect is aggravated, as in the case of Gobi, by the mountains and high lands which enclose this region on every side except the northwest. The small rain-fall in Peru is obviously the effect of the Andes upon the easterly winds which blow over them.

The small rain-fall which prevails in Southern California and from thence northward to Salt Lake, is due to the same causes which have been already explained, but their application is somewhat modified by the physical features of the country. Southern California lies in the same latitude as the northern portion of the Great Desert of Sahara. The prevalent winds here are similar to those near the northern margin of the Sahara, and if a great continent stretched eastward from Southern California without any considerable range of mountains, it is believed that it would show an immense desert similar to the Sahara. The small breadth of the American continent south of latitude 30°, together with the continuous chain of mountains which forms the great back bone of the American conti-

nent, prevents the eastward extension of this desert. But while the chain of the Rocky Mountains limits the desert region on the east, the desert is extended northward to Salt Lake by the influence of the mountain ranges on the east and west sides, operating in the mode already explained in the case of the desert of Gobi.

The following are believed to be the principal causes of excessive rain-fall:

1. The meeting of the northeast and southeast trade winds resulting in a great rain-belt surrounding the globe.

2. The irregular barometric depressions of the middle latitudes. The average track of great barometric depressions is not as distinctly marked by an excess of rain-fall as might be expected; nevertheless storm tracks exhibit a tendency to incline toward districts where the rain-fall is unusually great, e. g. Newfoundland, Iceland, coast of Norway, North Italy, etc.

3. Mountain ranges causing increased rain-fall on the side from which the prevalent wind proceeds, as shown on pages 16–18.

4. Proximity to the ocean, especially when the prevalent wind comes from the ocean, e. g. Western Europe; eastern coast of South America, Africa and Australia.

5. Capes and headlands projecting considerably into the ocean generally receive a greater rain-fall than neighboring districts, e. g. Cape Hatteras, Newfoundland, southwest coast of Ireland and England, Cape of Good Hope, etc.

The following are some of the causes of deficient rain-fall:

1. A nearly uniform direction of the winds throughout the year, such as prevails within a portion of the system of the trade winds, especially in mid-ocean, and to some extent over the continents; e. g. Ascension Island, the Sahara, Southern California, South Africa and Australia.

2. The prevalent wind, having passed over a range of elevated mountains, descends upon the leeward side, e. g. desert of Gobi, Tartary, Chili, North America east of the Rocky Mountains, central portion of Spain, etc.

3. Ranges of mountains so situated as to obstruct the free movement of the surface winds toward a central region, e. g. desert of Gobi, Tartary, Southern California, Salamanca in Spain, etc.

4. Remoteness from the ocean measured in the direction from which the prevalent wind proceeds. There is a marked diminution in the mean annual rain-fall as we advance eastward from Western Europe. A similar effect is noticeable in many other parts of the world, but it is generally complicated by the combination of other causes.

5. High latitude. Beyond the parallel of 60° N. latitude, at

a little distance from the ocean, the mean annual rain-fall seldom much exceeds 10 inches; and there are apparently regions of great extent in Asia and North America where the annual rain-fall is less than 10 inches.

When we attempt to explain in detail the peculiarities of the rain-fall in all parts of the world, we find some perplexing cases. The principles above stated naturally lead us to infer that in the United States on the west side of the Alleghany Mountains the rain-fall should be greater than the average, and on the east side it should be less than the average. Schott's map of rain-fall does not indicate such an effect very distinctly, and some may hence conclude that the laws above stated cannot be general. It may be urged in reply that the slope of these mountains is generally quite gradual, and that the effect of elevation is less than it would be if the ascent were more precipitous; also that the proximity to the ocean probably balances in some degree the deficiency of rain-fall which would otherwise exist on the eastern side. Nevertheless it seems incredible that this range should not exert a palpable influence on the amount of the rain-fall, particularly between the parallels of 34° and 38°. Such an influence is somewhat obscurely indicated by Schott's map of rain-fall (1880). That the indications are not more palpable I ascribe to the following circumstances. 1. The observations at the different stations compared were made on different years. 2. The observations were generally made by volunteer observers, and no uniform system of observation was maintained either with respect to the form of the gauge, its height above the ground, freedom of exposure and the mode of measuring the rain and snow; hence as might be expected the observations show excessive anomalies. 3. The stations employed were determined entirely by the convenience of the observers, and their location is not well adapted to indicate the influence of this mountain range. Among all the stations reported in Schott's Tables (1872) the highest one, east of the Mississippi River, is Somerset, Pa. (height 2195 feet); there are four stations of 2000 feet elevation; one of 1720 feet, one of 1530 feet and one of 1502 feet, and these are all the stations (8 in number) whose height exceeds 1500 feet. If a sufficient number of suitable stations were selected, and observations were continued for a few years, it is not doubted that they would show that the Alleghany Mountains exert an appreciable influence on the amount of the annual rain-fall. It is not, however, believed that this influence is as decided as that of the mountains on the northwest coast of America, or those on the coast of Norway. The Alleghany Mountains correspond more nearly to the Ural Mountains in Russia, whose influence upon the rain-fall is small, but nevertheless appreciable.

Mount Washington in New Hampshire exerts a marked influence upon the rain-fall. Here the mean annual precipitation is 77 inches, while in the surrounding districts the mean annual fall is only 40 inches. The general features of the rain-fall in North America conform closely to the principles above enunciated, and it is believed that most of the anomalies which now exist will disappear when we obtain more accurate observations extending over longer periods of time.

The distribution of the rain-fall in Western and Southern Europe presents some peculiarities the cause of which is not very obvious. Throughout a considerable portion of France, including most of the western coast, the annual rain-fall is less than 25 inches, and about Paris it is less than 20 inches. This small rain-fall may be due in part to the small elevation of this district above sea-level, but apparently it is also connected with the average paths of storm centers. Near the coast of Europe, storm centers generally pass north of Scotland; and those which pass south of England appear to incline towards the mountain ranges of North Spain and Switzerland, thereby leaving over France a region where barometric minima are comparatively infrequent. Hungary also is a district of small rain-fall, apparently resulting from the mountain ranges by which it is enclosed.

The small rain-fall at Cumana (No. 708) is apparently due to the high hills which enclose it on all sides except the west. I do not think however that the mean annual rain-fall at Cumana is as small as seven inches. The result given in the table depends solely upon the observations of Humboldt made in 1799, and the rain which he reports all fell in two months, September and October. Probably this does not represent the entire rain-fall of that year, and 1799 may not have been an average year. It is difficult to reconcile some of the statements made with regard to the rain-fall in South America. Humboldt says (vol. vi, p. 789), "in the new continent, the drought of Cumana, Punta Araya and the island of Marguerita can be compared only with the province of Ciara in Brazil, where sometimes (1792–1796) it does not rain during several years." According to a statement in Nature, vol. xviii, p. 385, Ciara (No. 351) is subject to periods of severe drought and also to remarkable floods, but the mean annual rain-fall is 52 inches. I do not question that the average rain-fall at Cumana is small for that latitude, but it does not seem possible that it can be as small as seven inches.

The accompanying map represents pretty well the observations in the preceding catalogue. The chief exceptions are, 1. A few cases of anomalous rain-fall apparently restricted to a small geographical area. 2. A few cases of observations em-

bracing only a short period of time when it was thought that a longer series of observations would cause the anomalies to disappear. If any person whose attention is attracted to this map should discover in it serious defects, he is urgently solicited to communicate to me the observations which indicate these defects. In my next paper I propose to publish all additional observations of rain-fall which I may be able to obtain; and if the present map should be found greatly in error, I intend to issue a revised edition of it.

Art. II.—*Post-Glacial Joints;* by G. K. Gilbert.

The following communication is based upon observations made by the writer as a member of the United States Geological Survey.

The Sevier Desert lies in Utah, immediately south of the Great Salt Lake Desert. Each is a flat, white plain, surrounded by mountains, and each has its salt lake filling its lowest depression. The mountains are all ridges with axes trending north and south, and those which lie between the plains are separated from each other by trough-like valleys through which one may travel from desert to desert without great ascent. During the Glacial Epoch both deserts were covered by water, and the two floods were united by a series of straits so as to make a single lake—the Lake Bonneville of geologists. From this were thrown down a series of fine sediments—clays and marls—which now constitute the floors of the deserts. When the climate changed at the close of the Glacial Epoch the water gradually dried away, and as it fell there came a time when the bottom of the deepest strait was laid bare and the lake was divided into two—the representatives respectively of Great Salt Lake and Sevier Lake. Their separation was not, however, at first complete, for Great Salt Lake fell the more rapidly, and there was a transition epoch during which Sevier Lake overflowed to Great Salt Lake. A channel of outflow was eroded in the lake sediments, cutting them to a depth of more than one hundred feet; and this channel is plainly to be traced at the present time. Indeed it is so conspicuous a topographic feature that it has been named by travelers the "Old River Bed," and a stage station on the old overland road was called "River-bed Station."

One day last summer I stood on a rocky butte which springs from the Salt Lake Desert at its southern margin just at the brink of the Old River Bed. Behind me at the south there were other rocky buttes, and beyond them mountains; and

before me the desert stretched for a hundred miles—a white, glaring plain, interrupted here and there by insular rocky ridges, but for the most part as smooth as a floor and almost as bare. Through it the Old River Bed meandered for twenty miles, a solitary and abandoned water-course. As I gazed my attention was caught by a peculiarity of the farther bank of the river-bed, at a point two miles away. The scant rains of to-day are washing the silt of the plain from either side into the ancient channel, and are at the same time eroding small lateral channels. The peculiarity which attracted my attention was the parallelism and straightness of a group of these small lateral channels, and a brief inspection led to the conviction that their arrangement was too systematic to be fortuitous. Other duties prevented me from making a closer examination, but my companion and assistant, Mr. Israel C. Russell, was enabled to do so the following day, and he found that the details of the drainage were controlled by a compound and extended system of joints. The principal series trend almost precisely north and south and a subordinate series east and west. They all are vertical and straight and (within each series) closely parallel. They are readily traced from top to bottom of the walls of the lateral ravines, and not infrequently a wall exhibits a broad, flat, sheer face caused by the removal of the clay from one side of a plane of jointing. Elsewhere the faces of the bluffs are buttressed by square pilasters, or ornamented by outstanding rectangular columns, the forms of which have been determined by the two systems of joints. The main arroyos leading up from the river-bed are controlled by the main system of joints, but at a short distance back from the bluff there is a tributary drainage at right angles to the primary, and controlled by the cross joints. The edge of the desert plain is thus marked out in a series of rudely rectangular blocks which may be regarded as the incipient stages of the pilasters of the bluff.

The lamination of the clays and marls in which the joints occur is traceable across them, showing that there have been no faults upon their planes; and the absence of faults is quite as strongly attested by the perfect continuity of the even surface of the plain at a little distance from the river bed.

Mr. Russell's observations showed that they were not restricted to the spot where they were first detected but were discernible generally along the margin of the river-bed. It is impossible to trace them upon the adjacent plain, but there can be little doubt that they extend beneath it. The surface is converted by every shower into a plastic mud and in that condition is welded into continuity and all trace of structure is obliterated. For aught that is known to the contrary they may exist in the lake beds beneath the surface of the entire desert.

The point of especial interest is that these joints have been developed in post-Glacial time within a series of strata not perceptibly indurated, and which repose undisturbed in the place where they were deposited. The strata are nearly horizontal and their inclination of less than one-half a degree, northward, is presumably the original slope of the bottom upon which they were thrown down. Within the basin of the ancient lake there have been small orographic movements since the Glacial Epoch and a few faults are known to have taken place but no evidence has been found of such disturbances in the vicinity of this locality. The lake-basin has been the scene likewise of post-Glacial volcanic eruption but the nearest locality is eighty miles distant from the Old River Bed.

I am not aware that any satisfactory explanation has ever been given of the origin of the jointed structure in rocks and I have none to propose. They have, however, been heretofore associated in my mind first, with induration, and second, with orographic displacement, and their discovery in undisturbed and unindurated rocks was therefore a matter of surprise. The observation is believed to be exceptional and is here published in the hope that it will aid some one specially conversant with the subject in the establishment of the true theory of the origin of the structure.

Art. III.—*On Sound-Shadows in Water;* by John LeConte.

1. More or less perfect Sound-Shadows thrown by hills, buildings, piers, and other obstacles to the transmission of aerial vibrations, must be within the experience of all. Nevertheless, the boundaries of such shadows are so imperfectly defined, that they can hardly be compared, except in a general way, with those of light. Moreover, in some cases, the obstacles placed in the route of the sound-waves, being elastic, propagate, more or less perfectly, the sonorous vibrations of the air through their thickness; so that, under these conditions, it is similar to producing a light-shadow by means of a transparent or translucent body.

2. But even in cases in which the sound-vibrations in air are not sensibly transmitted through the intervening obstacle, the boundaries of the sound-shadows are necessarily very imperfectly defined; for the amount of diffractive divergence proceeding from the secondary waves, originating at the boundaries of the obstacle, and propagated within the geometrical shadow, is usually so considerable, that the diminution of intensity of sound behind it, although quite perceptible, is by no means so conspicuous as might be expected.

3. The contrast, in this respect, between sound and light is well expressed by Lord Rayleigh: "When waves of sound impinge upon an obstacle, a portion of the motion is thrown back as an echo, and under cover of the obstacle there is formed a sort of sound-shadow. In order, however, to produce shadows in anything like optical perfection, the dimensions of the intervening body must be considerable. The standard of comparison proper to the subject is the wave-length of the vibration; it requires almost as extreme conditions to produce rays in the case of sound, as it requires in optics to avoid producing them."* In other words, the difference between sound and light results from the well-known fact, that an ordinary obstacle bears an immense ratio to the length of a wave of light; but does not bear a very great ratio to the length of a sound-wave. Hence it follows from the mathematical theory of undulations, that the waves of sound bend around obstacles, and produce more or less effect within the geometrical shadow; whereas light-shadows have definite boundaries and are more sharply defined. For in the case of light, calculation shows that at any point decidedly within the geometrical projection of the obstacle from the luminous source, the disturbance vanishes, while at any point outside of the geometrical projection, the disturbance is the same as if the primary wave had passed the screen unimpeded. But this is only partially true in the case of ordinary sound-waves, in consequence of their considerable length; it is rigorously true only when, as in optics, the diameter of the obstacle is large in comparison with the wave-length.

4. There are, however, other causes depending upon the differences between the sense of hearing and of sight, which doubtless render the appreciation of the shadows of sound much less distinct than those of light. On this point, Lord Rayleigh justly remarks: "In many cases, sound-shadows appear much less perfect than theory would lead us to expect. The anomaly is due in a great measure, I believe, to an error of judgment, depending on the enormous range of intensity with which the ear is capable of dealing. The whistle of a locomotive is very loud at a distance of ten yards. At a mile off the intensity must be 30,000 times less; but the sound still appears rather loud, and would probably be audible, under favorable circumstances, even when enfeebled in the ratio of a million to one. For this reason, it is not easy to obtain complete shadows."† In other terms, the range of audition is so extensive, that the diffractive secondary waves originating at the boundaries of the obstacle and propagated into the geometrical shadow, though comparatively feeble, produce decided sensuous impressions upon the auditory apparatus of the ear.

* "Theory of Sound," vol. ii, p. 106, art. 283. London, 1878.
† Phil. Mag., 5th series, vol. iii, p. 458, 1877.

5. The mathematical theory of undulations indicates that acoustical shadows should be more distinct for short waves than for long waves. This prevision has been verified by the experiments of Lord Rayleigh;* who found that the sound-shadows cast by acute sounds were more distinct than those produced by grave sounds.

6. Another prevision of theory has been experimentally verified both in the case of light and of sound. It is well known that the great geometer Poisson, in applying Fresnel's integrals to the case of the diffraction of light produced by a small opaque circular disk, was led to the startling result, that the illumination of the center of the shadow was precisely the same as if the disk had been altogether removed. This deduction from theory was experimentally verified by the illustrious Arago, by means of an opaque circular disk of 2^{mm} in diameter; for he observed a bright point in the center of the shadow of the disk on which waves of light were directly incident. In this case, the secondary waves originating at the disk find the conditions of complete concurrence at a definite point in the axis of the geometrical shadow.

7. The difficulties to be overcome, in the experimental verification of the acoustical analogue of this beautiful phenomenon, are entirely different from those of optics, on account of the immense disproportion of wave-lengths. In light, the disk must be small, and the luminous source must have a very small angular magnitude. In sound, the disk must be comparatively large, and the sounds must be acute. Lord Rayleigh has recently succeeded in experimentally verifying this prevision of theory in the case of sound, by means of a circular disk about fifteen inches in diameter, with a bird-call as the source of sound, placed at a distance of twenty inches from the center of the plane of the disk. At twenty-four inches on the farther side of the disk, the augmentation of the intensity of the sound, in the axis of the acoustical shadow, was obvious both to the ear and to a sensitive flame.†

Sound-Shadows in water.

8. It is a significant fact in relation to the phenomenon of acoustical shadows, that they seem to be more perfect or more sharply defined in water than in air. Thus, during the progress of the classical experiments of Daniel Colladon, in November, 1826, on the velocity of sound in the waters of the lake of Geneva, this physicist incidentally observed, that when the end of the hearing-tube (*cornet acoustique*), plunged into the water, was screened from rectilinear communication with the bell by

* Phil. Mag., 5th series, vol. iii, pp. 458, 459, 1877.
† Phil. Mag., 5th series, vol. ix, pp. 281, 282, 1880.

a projecting wall running out from the shore, whose top was above the surface of the lake, there was a very remarkable diminution in the intensity of the sound, in comparison with that observed at a point equally distant from, but in direct communication with, the source of sound, or out of the "acoustic shadow;" thus indicating the relative non-divergence of the rays of sound around obstacles in water, as compared with those in air.*

9. Another fact observed by Colladon during these famous experiments is, in this connection, no less significant. He found that the sound of the bell struck under water, when heard at a distance, has no resemblance to its sound in the air. Instead of a prolonged tone, a short sharp sound is heard, like two knife blades struck together. It was only within 200 meters that the musical tone of the bell was distinguishable after the blow. In air, it is well known the contrary takes place; the shock of the first impulse of the hammer being heard only in the immediate neighborhood of the bell, while the continued musical sound is the only one that affects the hearing at a distance.† Sir John Herschel, in his "Treatise on Sound,"‡ promised to explain this curious difference; but has not, as far as I can find, done so. Colladon § explains this phenomenon by the nature of the sonorous vibrations in water; showing that the duration of the sound will be much less when transmitted by water than when propagated by air.

Experiments of L. I. LeConte in 1874.

10. The preceding remarks show that comparatively few exact observations have been made on the obstruction produced by interposed obstacles to the propagation of sound-waves in different media. The following experimental results in relation to acoustical shadows in water may be of interest to physicists. The experiments were executed in 1874,‖ at my suggestion, by my son, L. I. LeConte, during the engineering operations incident to the removal of "Rincon Rock," a sandstone reef in the harbor of San Francisco (near the southeastern water front of the city), by means of "surface blasting" with "giant powder" or dynamite. The depth of water on the reef was about fifteen feet at low tide, with an extreme tidal range of about six feet. The "cans" or "cartridges" of "giant powder" used contained each about fifteen pounds of the explosive compound, comprising about seventy-five per cent of nitro-glycerine.

* Ann. de Chim. et de Phys., 2d series, vol. xxxvi, pp. 256, 257, 1827.

† Op. cit. supra, p. 254.

‡ Encyc. Metrop., art. 101.

§ Op. cit. p. 255.

‖ The long delay in writing out the notes of these experiments in form for publication has been due to domestic affliction and the subsequent pressure of perplexing duties.

11. *Effects of the explosive shock.*—It was observed that the suddenness of the shock imparted to the water by this explosive agent produced the most remarkable and astonishing effects. At the distance of 300 feet or more from the detonating cartridge, two distinct shocks were experienced. The first shock came through the intervening water, and was felt as a short concussion or click before there was any sensible elevation of the column of water resting over the point of explosion. The second shock came a little later by the air, and was heard. It was evidently communicated to the air by the water, at the time the elastic pulse transmitted by this liquid (the first shock) emerged, in a direction nearly normal to its surface, over a limited area around a point vertically above the exploding cartridge. This was obvious from the fact that aerial sound came from this region. The area, which was the source of the sound transmitted by the air, was the same as that from which the small jets of water (noticed hereafter, 14) were projected. The gases generated during the explosion came to the surface much later than this shock, and after elevating the column of water, over the position of the cartridge, to the height of twenty-five or thirty feet.

It is the character of the first shock that deserves special notice. To a person sitting in a small boat floating on the water at a distance of 300 feet or more from the point of explosion, with his feet resting on its bottom, the shock was felt as a sudden blow applied to the soles of the feet. In fact, it drove out the oakum from the seams in the bottom of the boat. When the observer stood on the top of a vertical wooden pile, this shock was felt as a sudden concussion coming up from the water along the cylinder of wood. The concussion produced by such an explosion was so violent that it killed or stunned the fish in the water within a radius of 200 or 300 feet from the explosive center. They rose to the surface in a helpless condition, and were secured by the boys.

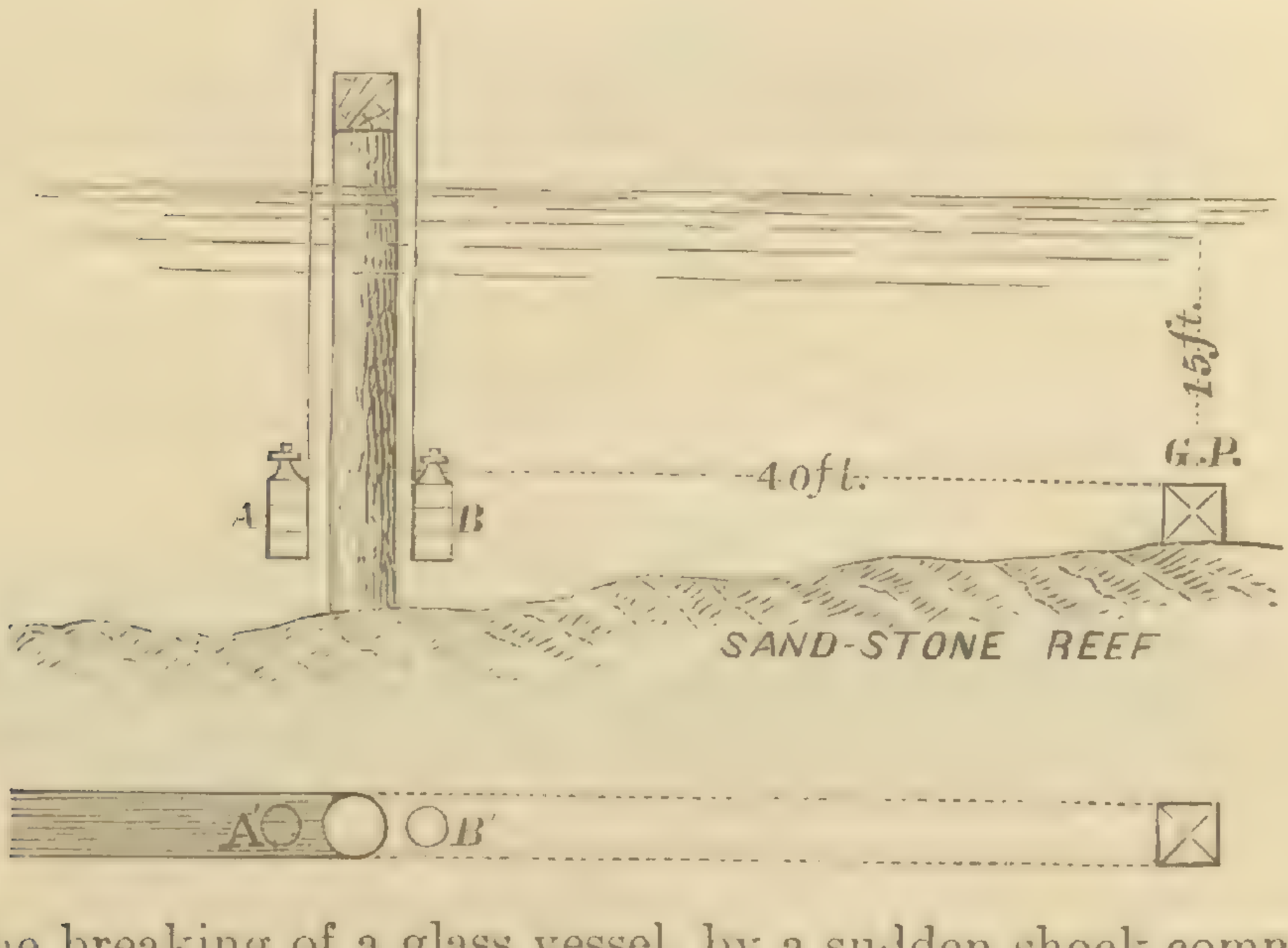
Experiments on Sound-Shadows.

12. *Experiments with stout glass (soda-water) Bottles.*—In these experiments the observer stood on the top of a vertical cylindrical pile (the trunk of an Oregon pine) about one foot in diameter, situated about forty feet horizontally from the explosive cartridge. The bottle being secured to a rigid rod was first plunged under the water from ten to twelve inches behind the pile (fig. 1, A), that is, within its geometrical shadow. The shock of the explosion did not injure the bottle. It was then plunged into the water in front of the pile (fig. 1, B), or outside of its geometrical shadow. In this position the bottle was shivered to atoms by the concussion due to the explosion. As

viewed from the experimenter's situation on the top of the pile, fig. 1, A′ and B′, indicate the two positions of the bottle in the preceding experiments.

The experiments were varied by plunging bottles into the water in various positions around the pile, within and outside of its geometrical projection from the explosive center; and in all cases they were protected from injury when within the geometrical shadow, and were shivered when outside of the same. The same results took place whether the bottles were filled with water or with air.

1.



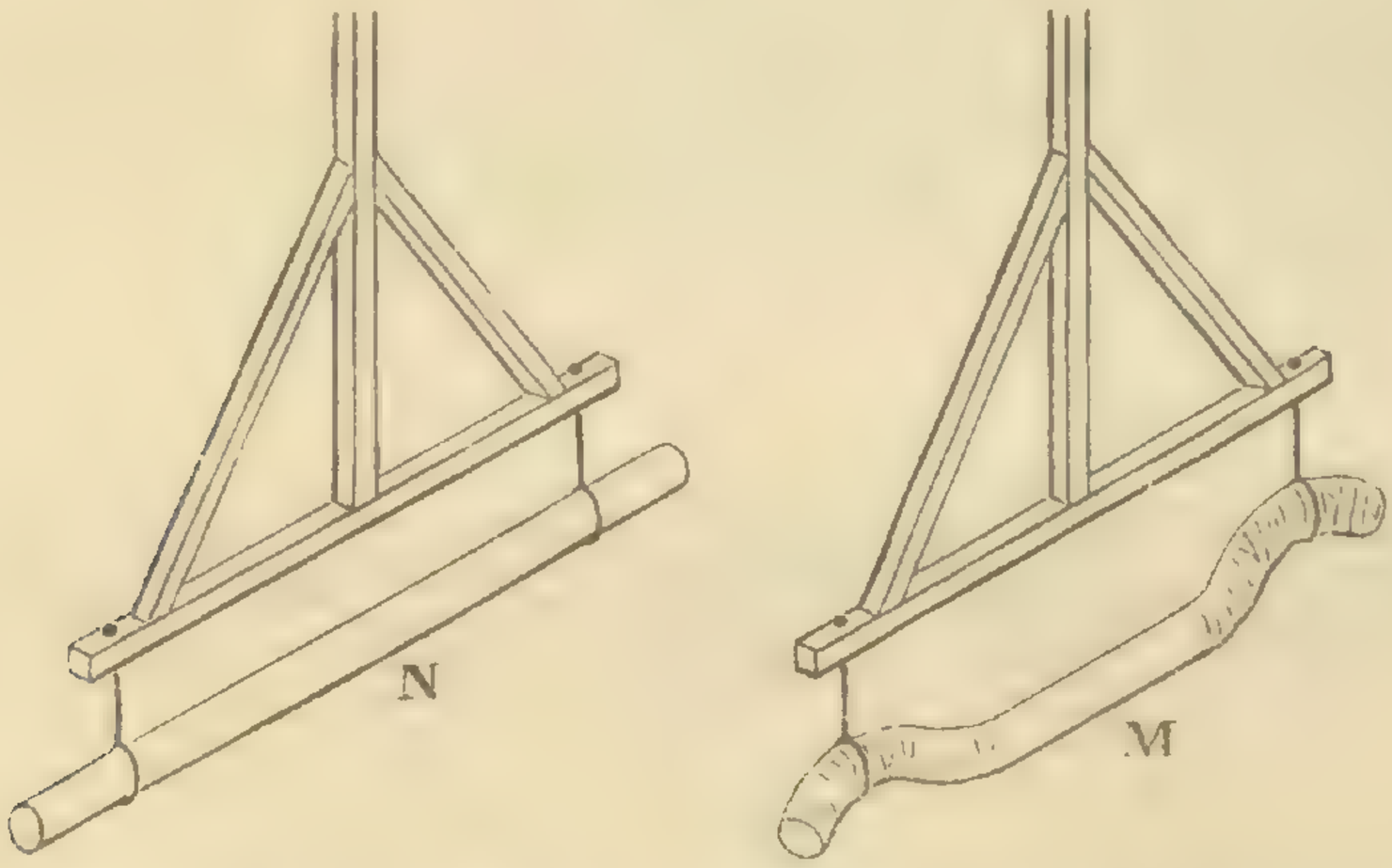
The breaking of a glass vessel, by a sudden shock communicated by means of water, is a fact long known, and is illustrated by the old familiar class experiment of exploding a "Prince Rupert drop" while its bulb is plunged into an ordinary apothecary's phial filled with water.

13. *Experiments with stout glass tubes.*—The cylindrical glass tubes employed were about 6 feet long, and 1·5 inches in diameter, the glass being about 0·5 of an inch in thickness. They were covered by pasting cartridge paper over them, so as to prevent the loss of fragments when breakage occurred. (See fig. 2, M).

The tubes were adjusted to a frame-work of wood so arranged (fig. 2, N) that they could be plunged in a horizontal position beneath the surface of the water behind the pile, the axis of the tube being at right angles to the plane of its shadow, and held there (the observer standing as before on the top), with the middle of the tube in the geometrical shadow, while the two extremities projected on either side about 2·5 feet beyond the boundaries of said shadow. (Fig 3, C and C′). In every

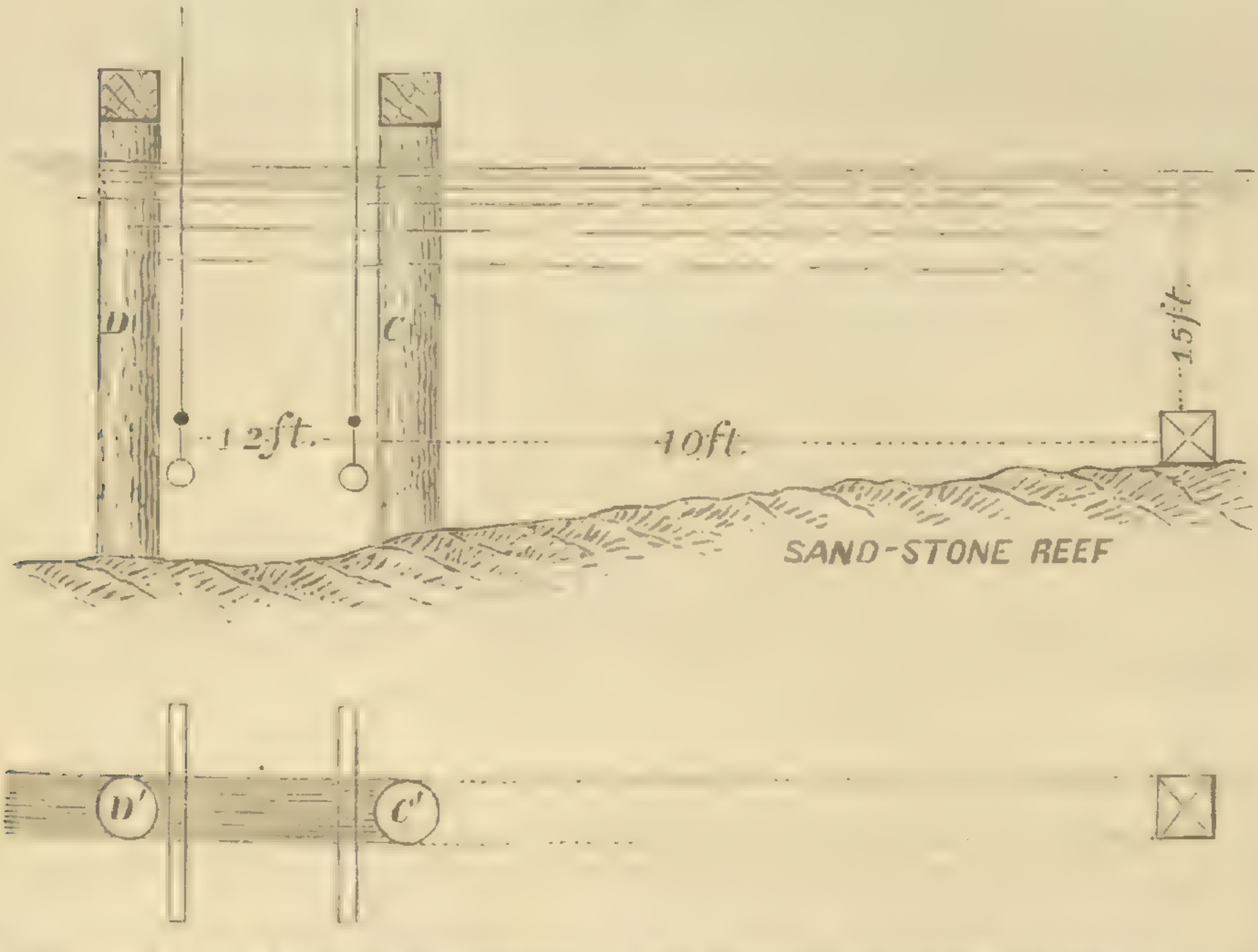
case the shock of the explosion shivered the projecting portions of the tube, and left the portion within the shadow uninjured. The boundaries between the broken and the protected portions of the glass were sharply defined.

2.



By standing on the top of a second pile, in the direction of the axis of the shadow of the first pile, and distant about 12 feet, the experiments were varied by plunging the frame-work and tubes—adjusted at right-angles to the plane of the prolonged shadow—into the water at this distance (12 feet) from

3.



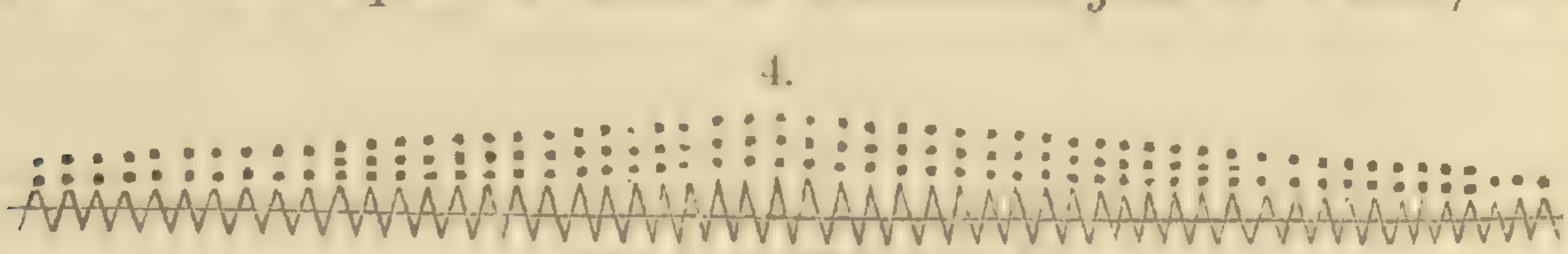
the obstacle which obstructed the sound-wave transmitted by the liquid. (fig. 3, D and D′). The shock of the explosion produced sensibly the same results as when the tube was near to the obstructing obstacle:—the protected portion of the horizontal glass tube was sensibly equal in length to the diameter

of the pile casting the shadow. Hence, the shadow of the cylindrical pile extended back for about 12 feet between sensibly parallel vertical planes, and its boundaries, at this distance, were still sharply defined.

It is evident that, if the explosive center were of insensible magnitude, the horizontal thickness of the geometrical shadow of the pile, at a distance of 12 feet beyond it, would be augmented in the ratio of 40 to 40+12, or of 40 to 52; these numbers being the distances in feet from the center. So that, if the thickness of the shadow at the pile were 12 inches, its thickness at 12 feet beyond would be 15·6 inches. If, however, the explosive energy occupied more or less space (as was the case in relation to the "giant-powder" cartridges), the thickness of the geometrical shadow, or umbra cast by the pile, might not increase sensibly with augmenting distance; and indeed, in case the exploding body exceeded 12 inches in diameter, the thickness of the shadow would diminish with increasing distance from the obstructing pile; as in the case of the umbra cast by an opaque body which is smaller than the luminous source.

14. *Another phenomenon observed.*—Another interesting phenomenon came under notice during the execution of these experiments. It was the singular effects observed on the surface of the water (when perfectly calm and glassy), for a certain area around the point immediately over the exploding cartridge. Simultaneous with the first shock (11) transmitted by the water —and before the ascending gases of explosion disturbed it—the surface of the liquid exhibited numerous jets of water, rising

4.



to the height of about 3 inches over the center of the area, and diminishing in height with augmenting distance from the center. The appearance presented was not unlike that produced by a heavy shower of rain falling on the calm waters of a lake. (fig. 4). To an observer in a boat floating on the adjacent water, and consequently viewing the phenomenon from a point near the water-level, there seemed to be a curious quincunx-like arrangement of the jets.

Explanation of the phenomena observed.

15. *Greater distinctness of Sound-shadows in Water.*—The much greater distinctness of acoustical shadows in water, as compared with those in air, appears to be pretty clearly established by the experiments of Colladon, and the fact seems to be abundantly confirmed by those which we have recorded in the preceding pages. This is an interesting and significant phenomenon in relation to the theory of sound. At first sight, it might be supposed that the difference is due to the greater velocity of propagation of the sound-wave in water. This may have been Sir John Herschel's idea, when he explains Colladon's results by reference to the greater elasticity of water.*

But, as already indicated (3), according to the mathematical theory of undulations the intensity of the effects, due to the secondary waves propagated into the geometrical shadow from the borders of the obstacle, is not directly dependent upon the velocity of propagation, but is properly a function of the wave-length: the diffractive divergence being less for short than for long waves. Hence it follows, that the distinctness of sound-shadows, like those of light, should depend upon the shortness of the wave-lengths. We have already seen (5) that the experiment verifies this prevision of theory in the case of sound-waves in air, by demonstrating that acute sounds cast more distinct shadows than grave sounds. Does this principle apply to sound-shadows in water?

Some physicists have attempted to explain the phenomenon of the great distinctness of sound-shadows in water, as indicated by the observations of Colladon (8), by assuming that the lengths of the sonorous waves propagated through water are much shorter than those transmitted through air.† But no reason is given for this fundamental assumption, other than that it is required by the demands of the theory of undulations, in order to account for the more perfect shadows in water. It evidently would be vastly more philosophical to establish as a matter of fact the greater shortness of the sound-waves in water, and thus to verify the deductions of theory. This we shall endeavor to accomplish.

16. *Measurement of Wave-lengths.*—With regard to continuous or musical sounds, we have the means of very readily determining the wave-length; for it is equal to $\frac{\text{Velocity of Sound}}{\text{Number of Vibrations.}}$ It is evident, therefore, that the number of vibrations or musical pitch of the sonorous body remitting the same, the wave-length in water, so far from being shorter, must be more than four times

* "Treatise on Sound," Encyc. Metrop., art. 102.

† Vide W. H. C. Bartlett's "Elements of Nat. Phil.," "Acoustics and Optics," 4th ed., N. Y. 1866. p. 75, art. 66.

as long as they are in air. Hence, according to theory, if Colladon's observations had been within the radius (200 meters) at which the musical tone of the sonorous bell was heard, the sound-shadows would have been less distinct than in air. Unfortunately, Colladon does not inform us at what distance from the vibrating bell his observations in relation to the acoustical shadows were made, so that it is impossible to apply this critical test of the theory of shadows. But the presumption is, that the observations were made in the neighborhood of Thonon (while the sonorous bell was placed at Rolle), at a distance of 13,487 meters from the source of sound; these being the arrangements during the execution of the experiments for determining the velocity of sound in the waters of the Lake of Geneva. At all distances from the bell greater than 200 meters, as we have seen (9), the sound lost its *musical* character and became short and sharp, like two knife-blades struck together. Hence under the assumption that the observations on sound-shadows were made very far beyond the limits at which musical tones were transmitted, we are precluded from determining the wave-length by the number of vibrations. It appears that in water, grave sounds are more rapidly suppressed or damped than acute sounds: so that at moderate distances from the sonorous center, only the short and sharp sound due to the shock of the striking hammer was transmitted to distant points through the water. It is obvious that the wave-lengths of sounds of this character must be determined by other considerations than those relating to the musical pitch.

In relation to solitary waves generated by sudden blows and explosions,* it may be more difficult to form a just estimate of the wave-length than in the case of musical sounds. Nevertheless it is evident that the wave-length must be directly pro-

* It may be questionable whether the elastic waves generated by momentary explosions or detonations can be properly regarded as strictly solitary. It is possible, that in such cases, groups of waves are generated, similar to those discussed by Lord Rayleigh in the Appendix to his work on the "Theory of Sound." Vol. ii, pp. 297–302.

Furthermore, the admirable and exquisitely refined arrangements devised by Regnault for investigating the phenomena of sound enabled him to submit this question to a more or less satisfactory experimental test, so far as aerial waves are concerned. ("Mémoires de L'Acad. des Sciences," volume xxxvii, pp. 45–49 et pp. 278–282, Paris, 1868.) He found that the explosion of a pistol charged with ordinary powder does not produce a single wave, since it gave rise to a recognizable musical tone of very brief duration (p. 45.); and the same was the case with the sound produced by the detonation of a mixture of oxygen and hydrogen gases (p. 48). But the explosion of a small charge of fulminate of mercury was so sudden that the wave generated in the air was much shorter, and the "coup" was much more "sée," than that which was produced by a pistol charged with ordinary powder. (pp. 47–48; and pp. 278–281). He adds. "Il est encore difficile de décider si l'on a produit ainsi une onde unique, mais il **est certain que** si plusieurs ondes prennent naissance, elles doivent se suivre de **trés près.**" (p. 48).

Again, the observations of General H. L. Abbot (U. S. Engineers), incident to

portional to the time occupied by the displacing impulse, multiplied by the velocity of transmission of the elastic pulse. In algebraic terms, if L=wave-length, t=time of the generating impulse, and v=velocity of sound in the elastic medium; we have, L varies as $t \times v$: or $L = t \times v$. Consequently, in a given medium, in which v remains constant, L will be a function of t, or the duration of the generative impulse; so that when the factor t is indefinitely small, the value of L will be correspondingly small. Hence, when the time of the blow or explosive impulse is exceedingly brief, the wave-length must be proportionately short.

17. *Application to Sound-Shadows.*—In the experiments of Colladon, if we assume that the brief shock of the hammer on a limited portion of the bell was alone transmitted to the distant observer, it is clear, that only the short sound-waves thus generated would reach the distant obstructing wall or screen in the water: and consequently, the greater definiteness of the acoustical shadows in water as compared with those in air would be the necessary result of the greater shortness of the sound-waves in water. Under the foregoing assumptions, the theory of undulations appears to afford a satisfactory explanation of the phenomenon observed by Colladon. Nevertheless, it would have been extremely interesting and instructive, as a very severe test of theory, had this distinguished physicist made observations on the relative distinctness of the sound-shadows in the water within the musical range of the submerged bell, as compared with those observed at points so remote that only the sharp blow of the hammer was audible in the water.

In like manner, the application of the principle of briefness of elastic-wave-genesis to the explanation of the phenomena observed by my son in his "Dynamite" experiments, is sufficiently obvious. In fact, all the phenomena incident to the explosion or detonation of the nitro-glycerine compounds indicate that the impulse generated is of indefinitely brief duration; indeed, its suddenness is almost beyond conception. Thus, a dynamite cartridge placed upon a log of wood, unconfined and free, with nothing above it except the atmosphere, will, when exploding, shiver the portion of timber under it to the heavy blastings at Hallet's Point, Hell Gate, in the harbor of New York, seem to render it at least probable, that the waves transmitted by the earth, reached the different observers in groups, or as a train of waves. (This Journ., vol. xv, (1878), p. 178 et seq.)

Sir G. B. Airy maintains that "there is reason to think that a single wave in air or in the medium of light would not produce the sensation of sound or color." (Undulatory Theory of Optics, p. 15, Art. 18.—1866). No reason is assigned for this somewhat extraordinary assertion. In the case of light it is obviously impossible to experimentally test the validity of this idea of the former Astronomer Royal; and it does not appear to be sustained by the results of acoustical experiments.

atoms:—The detonation being so instantaneous, that the superincumbent air, as well as the gases generated, having no time to be displaced, become a veritable tampon.

The efficiency of surface blasting under water, by means of these explosive compounds, depends upon this extraordinary suddenness of detonation, which renders the effect akin to that of the sudden blow of an enormous unyielding mass. It is evident, that the wave generated in an elastic medium like water, by an explosion of this character, must be very intense and very short. Hence, the acoustical shadow produced by an obstacle placed in its path of propagation, must, as in the case of light, be sharply defined and definite in its boundaries. Thus, the striking fact, that the protecting influence of the piles on the glass vessels plunged in the water was narrowly circumscribed within the limits of the geometrical shadow, may be rationally traced to the extreme shortness of the elastic waves, due to the inconceivably brief duration of action of the generative detonations. This view seems to afford a satisfactory explanation of the remarkable results revealed by the experiments in the harbor of San Francisco.

18. *Gun-powder explosions.*—If the foregoing is the true explanation of the definiteness of the sound-shadows cast in the preceding experiments, then the waves generated by the explosion of ordinary gun-powder, being less sudden, should not produce as sharply-defined shadows as those due to the detonation of dynamite. We have, so far as known, no specific experiments testing this point, but it seems to be quite reasonable that such will be found to be the case, whenever the test of experiment is applied. For it is well known that the subaqueous explosions of ordinary powder do not give rise to the remarkable concussions, so characteristic of the detonations of the nitro-glycerine mixtures.

19. *Dynamite explosions in Air.*—Moreover, if my explanation is correct, the acoustical shadows produced by nitro-glycerine detonations in air ought, also, to be more sharply defined than those due to sounds less suddenly generated. In other words, if the distinctness of sound-shadows depends upon the duration of the impulse which produces the accompanying sound-wave, then the definiteness of the shadows cast by sounds propagated through the air should vary with the suddenness of the action of the generating cause.

Inasmuch as the variations in the duration of the genesis of audible sounds in the atmosphere must, in ordinary experience, be very great, it may, at first sight, appear incredible that the corresponding differences in the perfection of sound-shadows cast by obstacles in the paths of different kinds of sounds, should have escaped the most casual observation. But it

must be recollected, that, for the reasons already assigned (1), (2), (3) and (4), aerial acoustical shadows are not readily appreciated by the ear. Moreover, in the case of sounds transmitted by the air, the distinctness of such shadows is most seriously impaired by the numerous reflected waves which come from circumjacent objects. It should be borne in mind, that it is only very recently (5), that the influence of acuteness of sounds on the distinctness of the resulting shadows, has been satisfactorily verified by experiment. In like manner I venture to predict that careful experiments will verify the deduction that the shadows due to sounds generated by the extraordinarily brief detonations of dynamite are more sharply defined, than those owing their origin to sounds less suddenly produced.

In confirmation of the foregoing view, the following observation may be cited: On the 16th of April, 1880, an explosion of about 2000 or 3000 pounds of a nitro-glycerine compound occurred at the "Giant Powder Works," situated under a bluff on the eastern shore of the Bay of San Francisco, at a distance (determined by triangulation), of 16.201 feet (4938 meters), in a direct line, in a northwest direction, from my room in the University building. About twenty-five adult men, a majority of them Chinamen, were literally blown to atoms; no one escaping to reveal the cause of the accident. The concussion at the University buildings,—more than three miles distant,—was sufficient to break about a dozen panes of stout window-glass on the side next to the explosive center. Nearly every person about the University grounds experienced two distinct shocks; one transmitted by the air, and the other by the ground. The cottage occupied by my brother (Professor Joseph LeConte), was situated in the geometrical shadow of one of the buildings; being about 890 feet on the farther side of it. No aerial shock was experienced by him or any member of the household: and the concussion transmitted by the earth was alone felt as a shock emanating from the floor. In other terms, the acoustical shadow cast by the intervening structure completely cut off the sound-wave coming by the air. It is scarcely necessary to add, that for ordinary sounds such would not have been the result.

20. *Phenomenon of Jets.*—The singular phenomenon observed by my son (14), of numerous small jets projected from the surface of the water when the shock transmitted by the liquid reached the surface-area above the exploding cartridge, was probably due to the circumstance that when the short and intense elastic wave emerged in a direction normal or nearly normal to the aqueous surface, the tense superficial capillary film yielded to the sudden impulse more readily at some points

than at others. The sensibly homogeneous character of such a tensile elastic film, would naturally tend to group the points of rupture, or jets of water, into more or less perfect order, partaking more or less of geometrical symmetry. Hence, the curious quincunx-like arrangement of jets as viewed by the observer near the water-level. According to this view, the phenomenon in question seems to find its counterpart or analogue in the more or less symmetrical forms produced by the intersection of the lines of rupture as the result of the tensional strains due to the contraction of homogeneous masses, during the process of cooling or of desiccation. Thus, the columnar structure of certain igneous rocks seems to be due to the tensile stress of contraction by cooling after solidification supervened; while the analogous structure developed by the desiccation of homogeneous masses of moist clay, mud or starch, appears to be produced by a similar strain consequent upon shrinkage from loss of moisture. In a similar manner, the tense superficial capillary film of the water, when it experiences the sudden molecular impulse due to the emergence of elastic pulse, is ruptured along lines more or less symmetrically disposed on the surface of the water; and the liquid beneath is projected through these lines or points of least resistance.

Berkeley, California, October 25th, 1881.

Art. IV. — *On the Connection between the Cretaceous and the recent Echinid Fauna*; by Alexander Agassiz.*

One of the very first results clearly indicated by the deep dredgings of Count Pourtalès, and the subsequent investigations of the "Porcupine" expedition, was the antique character preserved by many of the new genera discovered in deep water, and especially their resemblance to Cretaceous genera; and the study of the Challenger Echinids has brought this out still more plainly.

For the purpose of making the comparison of the Challenger Echinids with the earlier Cretaceous types as complete as possible, it will be interesting to take a rapid review of the Cretaceous Echinid fauna, and to contrast it with the abyssal fauna as a whole, independently of its combinations in time with the littoral and continental types, but not independently of its combinations with those types which extend into the abyssal fauna either from the littoral or from the continental fauna.

* From pages 25 to 30 of the Report on the Echinoidea of the Voyage of H. M. S. Challenger, by A. Agassiz.

On comparing the genera characteristic of the Chalk with those now found living, we find that a considerable number of the latter date back to the Cretaceous period; and a few of the Cidaridæ, the Echinidæ, the Salenidæ, the Echinoconidæ, and the Petalosticha, even to the earlier epochs, to the Jurassic beds, the Lias and the Trias. The genera *Dorocidaris*, *Phyllacanthus*, *Porocidaris*, *Salenia*, *Podocidaris* (*Magnosia*, *Codiopsis*), *Asthenosoma*, *Phormosoma* (*Echinothuria*), *Temnechinus*, *Cottaldia*, *Phymosoma*, *Holopneustes*, *Hemipedina*, *Echinus*, *Echinocyamus*, *Fibularia*, *Echinolampas*, *Rhynchopygus*. *Conoclypus* (*J.*), *Echinobrissus*, *Catopygus*, *Pygaster*, *Pourtalesia* (*Infulaster*), *Hemiaster*, *Periaster* are in this category, so that a good proportion of the genera of Echinids still living in the present epoch belong to genera already existing at the time of the earliest Cretaceous formations. And leaving out, for the present, the genera which have disappeared during the Tertiary times, we find in the Tertiaries, in addition to the above genera, the following which have continued to the present time: *Arbacia*, *Cœlopleurus*, *Echinometra*, *Stomopneustes*, *Strongylocentrotus*, *Sphærechinus*, *Temnopleurus*, *Trigonocidaris*, *Salmacis*, *Amblypneustes*, *Toxopneustes*, *Hipponoë*, *Clypeaster*, *Echinanthus*, *Laganum*, *Echinarachnius*, *Arachnoides*, *Echinodiscus*, *Mellita*, *Encope*, *Echinonëus*, *Nucleolites*, *Homolampas*, *Palæopneustes*, *Spatangus*, *Maretia*, *Enpatagus*, *Lovenia*, *Breyma*, *Echinocardium*, *Brissopsis*, *Agassizia*, *Brissus*, *Metalia*, *Meoma*, *Linthia*. *Schizaster*, *Moira*.

Leaving, as genera belonging strictly to the present epoch, which, for the present, we may take as the result of the existing condition of things and as the successors of the Cretaceous and of the Tertiary forms, the following only, *Stephanocidaris*, *Goniocidaris*, *Diadema*, *Centrostephanus*, *Echinothrix*, *Astropyga*, *Aspidodiadema*, *Micropyga*, *Colobocentrotus*, *Heterocentrotus*, *Parasolema*, *Pseudoboletia*, *Echinostrephus*, *Pleurechinus*, *Microcyphus*, *Mespilia*, *Prionechinus*. *Evechinus*, *Peronella*, *Astriclypeus*. *Rotula*, *Neolampas*, *Anochanus*, *Palæotropus*, *Clionobrissus*. *Echinocrepis*, *Spatagocystis*, *Cystechinus*, *Argopatagus*. *Palæostoma*, *Tripylus*, *Faovina*.

From our study of the embryonic stages of the Echinidæ, the Clypeastridæ, and the Spatangidæ, and a comparison of these stages with the genera of the Desmosticha and Petalosticha which have either succeeded the genera above mentioned, or have lived with them during the Cretaceous period and have disappeared either during the Cretaceous or the Tertiary periods, we find no difficulty in tracing an unbroken systematic connection from the earliest Cretaceous beds to the present time. But this connection is so complicated, and ramifies in so many directions, that it must be hopeless, even with the small number of species of Echinids known, to attempt to

do more than to indicate the lines of affinities, the delicate threads of which we can trace in characteristics of genera which at any special epoch seem to have little or no structural affinity. Let us take, for instance, the genera characteristic of the Chalk, and attempt to trace their connection both backward and forward in time.

Taking these genera in their most extended signification, and more especially those characteristic of the Lower Cretaceous formations, *Cidaris*, *Orthocidaris*, *Phyllacanthus*, *Tetracidaris*, *Goniopygus*, *Codiopsis*, *Magnosia*, *Cyphosoma*, *Pseudocidaris*, *Orthopsis*, *Pedinopsis*, *Codechinus*, *Stomechinus*, *Acrosalenia*, *Echinothuria*, *Pygaster*, *Discoidea*, *Holectypus*, *Pyrina*, *Clypeopygus*, *Pygurus*, *Metaporhinus*, *Holaster*, *Toxaster*, and comparing them in the first place with the genera of the Lias as far as they are known, we find that, with the exception of *Cidaris* and *Hypodiadema*, the forerunners of the Cidaridæ and Diadematidæ, not a single form of the Echinidæ is represented.

To attempt to explain their relationship to the earlier types, we may say, in a very general way, that the Perischoechinidæ early show, on the one side, a tendency to limit the number of the rows of interambulacral plates: and, on the other side, a decided tendency to a splitting up of the ambulacral and interambulacral plates into numerous irregular rows; they are thus the only group leading directly to such types as Cidaris on the one side, and to the Echinothuridæ on the other, the genera *Tetracidaris* and *Echinothuria* in the Chalk being the representatives of these two groups of Palæechinidæ; while the presence of such a type as *Hypodiadema* early in the Trias may, perhaps, represent the reduction of the number of coronal plates in some as the earlier Echinids, while retaining the uniform tuberculation so characteristic of the Palæechinidæ, and retaining at the same time the proportionally broader ambulacral areas of some of the types. From the time of the Trias, the Cidaridæ have been a most persistent type, and the changes the members of the family have passed through are restricted to very narrow limits, with the exception of the aberrant genera *Heterocidaris*, *Tetracidaris* and *Diplocidaris*, which retain more or less Palæechinoid characters while taking on a more modern facies.

The relationship of the Echinothuridæ to the Palæechinidæ I have already insisted upon elsewhere, and their affinities to the recent Diadematidæ are most close. The relationship of *Hypodiadema* to *Diademopsis*, *Pseudodiadema*, *Hemipedina*, and to the whole group of Pseudodiadematidæ which culminates in the Chalk, and is only very scantily represented at the present day, is sufficiently near not to need any further elucidation. On the other hand, the development of the Echinidæ is some-

what more complicated, as the affinities of the genera from which we trace the development of the Echinidæ, the Arbaciadæ and the Salenidæ, is very close in the Liassic, the Jurassic and the Lower Cretaceous beds; where such types as *Acrosalenia*, *Hemicidaris*, *Glypticus* and *Rhymechinus*, show us how readily we may pass, on the one hand, to the Salenidæ and on the other to the Temnopleuridæ, the Echinidæ and the Arbaciadæ. It is, however, only when the interbranching affinities have not extended in too many directions that we can still easily follow the systematic connection, which is as close as we can possibly desire to have it. In fact it is so extended that we are at a loss to express it satisfactorily.

A few examples will suffice. From the development of *Salenia*, of *Echinus*, of *Temnopleurus*, and of *Arbacia*, we see that these show a very different degree of complication in their systematic relations to the genera which have preceded them in time. The *Saleniæ* retain the simple ambulacral system of the *Cidaridæ*, the small number of coronal plates, the small number of large primary interambulacral tubercles, the variable shape of the primary spines, the secondary papillæ, the large plates of the abactinal system; and, as far as these features in the Cidaridæ are related to the Palæechinidæ, the *Saleniæ* retain to a less degree the Palæechinid affinities of the Cidaridæ. But, in addition to this, we find in the *Saleniæ* the presence of a subanal plate, comparatively large ambulacral tubercles, a slight tendency in the ambulacral pores to deviate from the vertical arrangement of the Cidaridæ, and in the imbricating plates of the actinal membrane are apparently very decidedly different structural features. These last named features are all features which tend toward the Echinidæ proper, and which thus far have not appeared in the older Cidaridæ, though we find some of these characteristics already foreshadowed in the imbricating membrane of the Archæocidaridæ, and in the large primary ambulacral tubercles of the Hemicidaridæ. As far as *Echinus* is concerned, the want of prominence of the principal primary tubercles, as well as greater uniformity in the structure of the spines, recalls again the earliest Palæechinidæ, while the modifications of the ambulacral system also to a certain extent point back to an ambulacral system made up of a large number of plates, as we find most markedly shown again in the more recent Echinometridæ. The actinal membrane is further altered in the direction of that of *Salenia*; we have a smaller number of plates which in some genera are reduced to ten, the supports of the buccal tentacles, which are the only remnants of the former uniform extension of the ambulacral pores as far as the actinosome. In the structure of the apical system, the subanal plates can still be traced in some of the stages of

growth, while in the *Temnopleurus* it never becomes entirely obliterated. In *Temnopleurus* we might say the Salenid abactinal system was more readily traced, and still better in *Arbacia*, while in both these genera the Cidarid features of large primary tubercles is retained in a different degree; and in *Arbacia*, in one part of the ambulacral zone, the arrangement of the pores is of an ancient type, while toward the actinosome its petaloid structure is eminently recent: the structure of the ocular plate of *Arbacia* leads us back directly to the structure of the ocular plate in the oldest Palæechinidæ.

The affinities of the Clypeastridæ with the Discoidæ are clearly indicated by the development of the longitudinal axis, which dates from the exclusion of the anal from the spinal system. We readily trace through *Pileus*, *Holectypus* and *Discoidea* affinities to *Galerites*, and the fossil Conoclypeidæ, while with the appearance of *Galerites*, *Fibularia*, and *Echinocyamus* we have the element of the Clypeastridæ and Scutellidæ; and their relationship to the Cassidulidæ is well shown in the simple ambulacral system of some of the genera, and the rudimentary auricles are still to be traced among the Echinolampadæ, while the affinity of the earliest Cassidulidæ, *Hyboclypus*, *Galeropygus* and the like, to *Pygaster*, which culminate in our day with but slight modifications in *Echinoneus*, show how clearly related the earlier Spatangoids were with the genera to which the Clypeastroids are most closely related, which in their turn will show a most unmistakable relationship to the Desmosticha, so much so that it seems difficult to say whether some of the Echinolampadæ of the present are not more closely related to the Galeritidæ, from the slight development of the pelatoid system, and the presence of jaws or of rudimentary auricles.

Already, in the Jura, *Pygaster* shows the method of the passage of the anal system from the interior of the anal ring to the odd interambulacral space, and we find genera such as *Holectypus* and *Discoidea*, in which it occupies in succession all possible positions between the apical system and a place close to the actinosome; and, the passage once effected in the Clypeastroids, we readily go from a mere circular or elliptical opening placed either in the axis, or obliquely or transversely to it, to an opening in a slight groove or a more or less deep groove occupying this same odd interambulacral space, having its climax in the Echinobrissinæ: and then we most naturally pass to an opening holding a certain relation to a more or less distinct beak which, combined with the subanal plastron enclosed by the subanal fasciole, we can gradually trace from a simple plastron flush with the test, as in the earliest Holasteridæ, to the Echinocardiæ, to the Brissinæ, and finally to the Pourtalesiæ, to a plastron extending as a slight beak below the anal system, and fin-

ally forming a more or less distinct snout; and when this is combined with the deep anal groove of other Spatangoid genera we get the remarkable forms such as we have described as belonging to the Pourtalesiæ.

The type of *Holectypus* with its regular outline, its buccal cuts, the anal system on the actinal surface, and the diminution of the size of the tubercles to uniformity in the two areas, the restriction of the poriferous zone to a single vertical row, all tend to show that the tendency to the Clypeastroids is already highly specialized. The existence of such forms as *Pyrina*, with their simple ambulacra leads directly to the Nucleolidæ and Echinolampadæ. On the contrary, we can only obtain such forms as the present deep sea types from the earlier Cretaceous types like *Infulaster*, and their derivation from such forms as have been figured by Ooster (Echin. Alp. Suisses, pl. x, figs. 1–4) as *Dyaster calceolatus*. (See also de Loriol, Echinoid. Crét. de la Suisse, pl. xxxiii.)

When we take the Spatangoids of the Chalk, they lead us directly through the Palæostominæ and the Collyritidæ to the Ananchytidæ, which have persisted to the present day; and also to the Spatanginæ proper, represented by their few genera, such as *Micraster*, *Hemiaster*, and *Prenaster*, which already possess the structural features characteristic of the recent Spatangoids. That is, we find genera with a peripetalous fasciole, a subanal fasciole, sunken ambulacra, petals of a different degree of development, spines specialized on certain areas of the test, a trace of a sunken anterior groove, of an anal beak, of an actinal plastron, of a snout, of a lateral fasciole, and of a specialization of the primary and secondary tubercles. But, of course, the extent to which these features may be developed in Tertiary and recent genera contrasts often strikingly with the rudimentary nature of the structural features found in the Cretaceous or Tertiary genera. The simple actinostome of the Palæostominæ is combined with a well-marked specialization of the ambulacra above the ambitus, the petaloid feature of the early Spatangoids which appears later in the Cassidulidæ; while in the Ananchytidæ the well developed labium of all the more recent Spatangoidæ is combined with a comparatively more rudimentary state of the ambulacral zones.

Among the Cretaceous genera, *Hemipneustes* and *Enmalaster* are extremely instructive. They show, perhaps better than any others, the passage which exists between the earliest Spatangoids with more or less petaloid ambulacra, and the older Spatangoids without petals, and in which the ambulacra have the same simple structure from the apical system to the actinostome. In both these genera the petaloid structure is limited to the posterior poriferous zone of the lateral ambulacra; the only

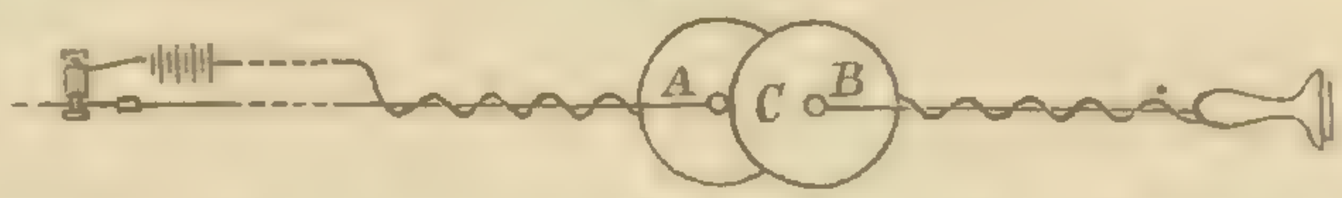
recent genus in which a similar structure still exists is *Agassizia*. In this genus, however, the posterior lateral petals are normally developed, as in other Spatangoids; or perhaps we must consider this as the last trace in normal Spatangoids of the simple condition of the ambulacra, such as we still find it in the Pourtalesiæ. It is specially interesting to compare these genera first to the Ananchytidæ, then to the Toxasteridæ; and finally to such recent genera as *Genicopatagus*, *Homolampas*, *Argopatagus*, and the like. These comparisons lead us to detect affinities in all possible directions, with the highly petaloid ambulacra of the Spatangoids, with the simplest ambulacral petals of the earliest Spatangoids, or with the embryonic ambulacra of the Pourtalesiæ proper.

ART. V.—*Upon an Apparatus for determining without pain to the patient the Position of a Projectile of Lead or other metal in the human body;* by ALEXANDER GRAHAM BELL.*

THE instrument I have the honor of presenting to the Academy has for its object the determination of the exact place occupied by balls of lead, fragments of shell, or metallic substances of any kind embedded in the body of a person wounded by fire-arms, and it may be considered as a form of the well-known Induction Balance of Professor Hughes.

This exploring instrument enables us to determine that position for the most part with very great exactness, and that without any pain to the patient, which is not the case when we use metallic probes which require to be brought into direct contact with the projectile.

1.



The instrument is composed essentially (fig. 1) of a system of two parallel flat coils (A and B) partially superposed upon one another in such a manner that the edge of one is nearly

* This instrument has originated from researches undertaken in the Volta Laboratory at Washington, on the occasion of the sad attempt upon the life of President Garfield. This note is preliminary to a paper which I shall publish shortly, giving a complete account of these researches. It was read before the French Academy.

So many different persons have been kind enough to give me the benefit of their suggestions and advice, concerning the method of exploration for this object, that I can only mention here the names of a few:

Prof. Hughes, George M. Hopkins, Sumner Tainter, Thomas Gleeson, Dr. Chichester A. Bell, Charles E. Buell, Prof. Simon Newcomb, Prof. H. A. Rowland, M. Rogers, Prof. John Trowbridge, J. H. C. Watts, the director of the Western Union Telegraph Co. at Washington, and the correspondent of the New York Tribune at Washington.

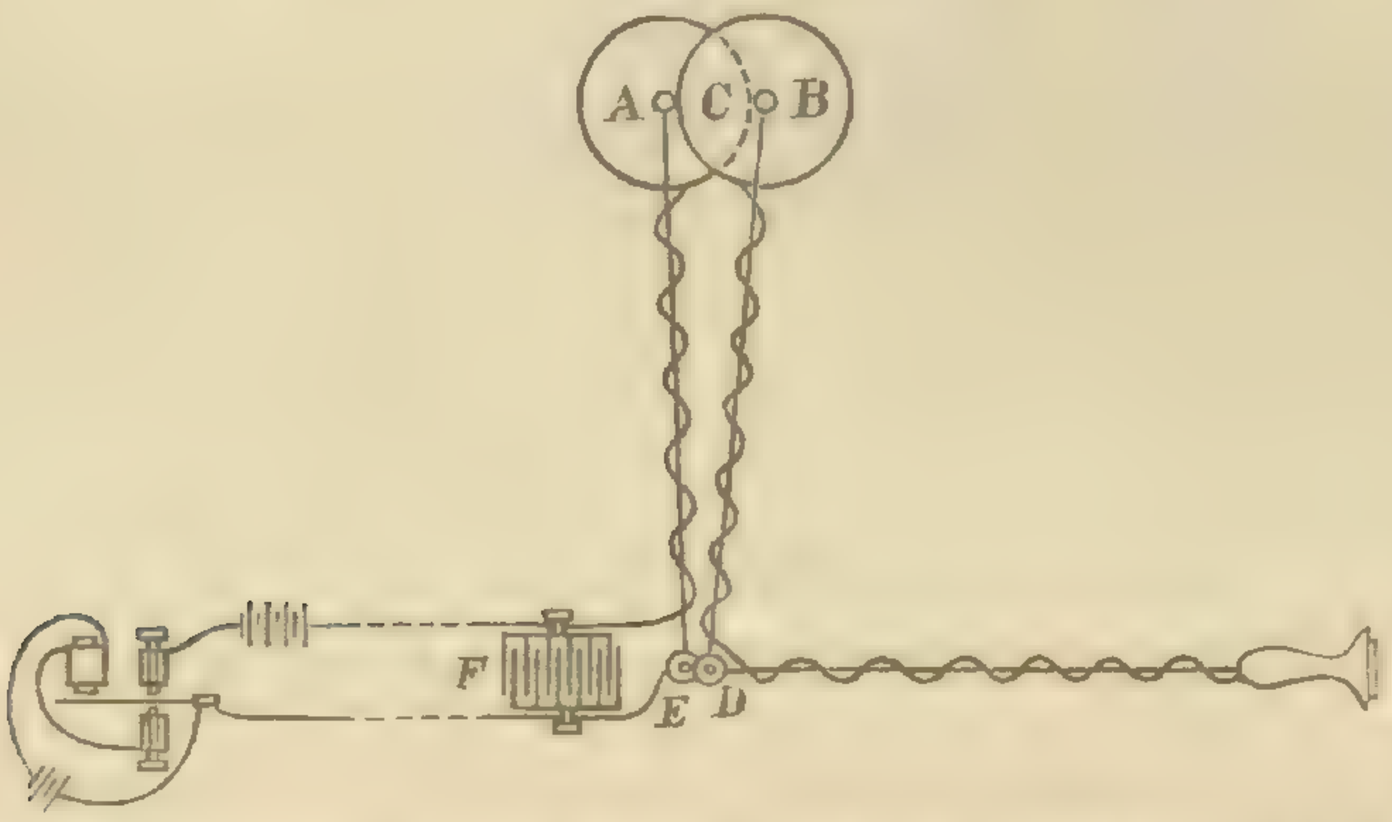
over the axis of the other. One of these coils (A) is made of thick wire constituting a portion of the primary circuit, and the other (B) of thin wire constituting a portion of the secondary circuit. Both coils are embedded in a mass of paraffine placed in the interior of a wooden case furnished with a handle.

A vibratory current from a galvanic battery traverses the primary coil, and the secondary circuit includes an ordinary telephone. Under these circumstances no sound is heard from the telephone, but if we cause any metallic body to approach the part (C) common to the two coils, the silence immediately gives place to a sound, the intensity of which will depend upon the nature of the metallic body, upon its form and upon its distance.

We may remark in this connection that the most favorable form that can be assumed by the projectile for which we explore, is that of a flat disk with its face parallel to the surface of the skin, and that the most unfavorable, a similar disk with its face perpendicular to the same surface.

It is difficult in practice to obtain the exact adjustment of the coils required, and it is therefore found advisable to introduce into the primary and secondary circuits respectively, two other coils (D and E, fig. 2) analogous to the first, but very much

2.



smaller, whose common surface can be modified by the play of a micrometer screw. By means of this fine adjustment we are able easily to reduce the telephone to the most complete silence. It should be added that the effects obtained, when a condenser (F) is introduced into the primary circuit, are much superior to those obtained without, as had been independently predicted by Professor Rowland of the Johns Hopkins University.

If we wish to ascertain the depth at which the metallic mass lies embedded, this is easily ascertained if we know *a priori* its form, its mode of presentation and its substance. It is then only necessary to adjust the apparatus to silence while it is applied to the skin; after which removing the apparatus, we bring near it another metallic mass similar to that explored for

so as to reproduce silence anew, and the distance of this mass from the exploring instrument gives the measure which it is desired to determine.

I conclude this note by relating an experiment made in the office of Dr. Frank Hamilton, of New York, on the 7th of October, last, in the presence of thirteen eminent surgeons.* The experiment was made upon the person of Col. B. F. Clayton, wounded in 1862. The ball entered in front through the left clavicular articulation, breaking the clavicle. Drs. Swineborne and Vanderpool supposed that it was lodged under the scapula, but my apparatus demonstrated on the contrary, that it was located in front and just below the third rib.—*Comptes Rendus*, Paris, Oct. 24, 1881, vol. xciii. p. 625.

ART. VI.—*Observations of the Transit of Mercury*, 1881, *November 7, at Mount Hamilton, California.* (Communicated by the Lick Trustees) by EDW. S. HOLDEN and S. W. BURNHAM.

PROFESSOR HOLDEN and Mr. Burnham were invited by the Lick Trustees to observe the transit of Mercury on the 7th of November, with the smaller instruments which have lately been set up at the Lick Observatory.

Professor Holden observed with a Clark comet-seeker of 4 inches aperture and a power of 50 diameters, the highest available. Captain R. S. Floyd, President of the Lick Trustees, observed with a small telescope, aperture $2\frac{1}{2}$ inches and power 56. Mr. Burnham observed with the 12-inch Clark equatorial (its aperture being reduced to six inches) and a power of 150 diameters. The assumed position of Mount Hamilton is

$$\varphi = +\,37^\circ\ 21'\ 3''.$$

$$\lambda = +\,2^h\ 58^m\ 14^s{\cdot}6 \text{ from Washington.}$$

The computed time of first contact is (using the elements of the American Ephemeris), $2^h\ 9^m\ 42^s{\cdot}3$.

The local mean times as observed were,

First Contact.

Holden	$2^h\ 11^m\ \ 2^s{\cdot}3$.
Burnham	$2^h\ 10^m\ 41^s{\cdot}1$; $H - B = +\,21^s{\cdot}2$.

Second Contact.

Holden	$2^h\ 12^m\ 25^s{\cdot}8$.
Floyd	$2^h\ 12^m\ 15^s{\cdot}0$; $H - F = +\,10^s{\cdot}8$.
Burnham	$2^h\ 12^m\ \ 5^s{\cdot}7$; $H - B = +\,20^s{\cdot}1$.

Duration of Ingress.

Holden	$1^m\ 23^s{\cdot}5$.
Burnham	$1^m\ 24^s{\cdot}6$.

* Drs. G. H. Gardner, G. Durant, Ed. Birmingham, N. Bozeman, L. Damainville, J. N. Hinton, Francis Delafield, F. H. Hamilton, D. Chamberlain, Elias Marsh, J. G. Johnson, Joseph Halderson and J. G. Allan.

SCIENTIFIC INTELLIGENCE.

I. PHYSICS AND CHEMISTRY.

1. *Lunar Disturbance of Gravity.*—Mr. G. H. DARWIN and Mr. H. DARWIN working upon a suggestion of Sir W. Thomson have been investigating experimentally the lunar disturbance of gravity and the question of the tidal yielding of the solid earth. The apparatus which they used was, in its main features, due to Sir W. Thomson and consisted of a solid lead cylinder, weighing a pound or two, which was suspended by a fine brass wire about five feet in length from the center of the cross beams of a solid stone gallows. A spike projected a little from the bottom of the cylindrical weight; a single silk fiber, several inches in length was cemented to this spike, and the other end of the fiber was cemented to the edge of an ordinary galvanometer mirror. A second silk fiber, of equal length, was cemented to the edge of the mirror, at a point near to the attachment of the former fiber. The other end of this second fiber was then attached to a support, which was connected with the base of the stone gallows. A small displacement of the pendulum in a direction perpendicular to the two silks caused the mirror to turn about a vertical axis. A beam of light was reflected from the mirror and received upon a scale. The movements of the mirror were found to be very irregular and several modifications were made in the apparatus. The pendulum was hung in fluid by two wires, and was free to oscillate only in one direction, and a suitable appliance was added by means of which the values of the deflections were obtained. It was found "that the pendulum was subject to a diurnal oscillation, and that it stood farthest north toward 6 P. M. and farthest south toward 6 A. M. Superposed on this was a gradual change of the mean diurnal position, for during two months the pendulum moved northward." The apparatus was extremely sensitive. "Water poured on the ground, at the basement of the stone gallows, tilted the whole structure, and small changes of temperature were found to give distinct effects; 1 foot of displacement in the spot of light on the scale corresponded to 1″ of change in the direction of the plumb line with reference to the base of the gallows." The suspension of the apparatus proved, however, to be unsatisfactory and further modifications were made with the improved apparatus; similar diurnal oscillations of the pendulum were again observed, and a similar slow change in the mean diurnal position, and the authors conclude that these changes indicate a real phenomenon and do not depend upon the errors of the instrument. Periods of continued agitation lasting for several days were also noticed. These periods do not seem to be connected with external meteorological conditions. The pendulum was not sensitive to local tremors but it was extraordinarily sensitive to steady forces. When a person

stood in a room sixteen feet from the instrument, and again at seventeen feet, the difference of pressure was distinctly shown by the pendulum. An alteration of the plumb line through $\frac{1}{100}$ of a second of arc was easily measurable. The experiments of the authors confirm the previous results of M. d'Abbadiela and also of M. Plantamour, who found that there were periods of agitation and quiescence of the earth's surface without reference to any perceptible external cause, and that there were gradual changes of level extending over several months, and indications of an annual inequality of level. In short the earth's surface appears to be in a state of continual movement. Previous experiments of Mr. Horace Darwin upon earth movements are also described. The authors suggest that greater precautions should be taken in the protection of piers for transit instruments. They have no hope of being able to observe the lunar attraction in the present site of observation, but think they may be able to devise a portable instrument which could be used at the bottom of a deep mine if a support sufficiently invariable could be found there. (Report of Committee of the British Association, consisting of Mr. G. H. Darwin, Sir W. Thomson, Professor Tait, Professor Grant, Dr. Siemens, Professor Purser, Professor G. Forbes and Mr. Horace Darwin, appointed for the measurement of the Lunar Disturbance of Gravity. Account of experiments by G. H. Darwin and H. Darwin; read at York, September, 1881.)—*Nature*, Nov. 3, 1881. J. T.

2. *On Drops floating on the surface of Water.*—Drops of water are frequently seen floating for some time on the surface of water before they disappear. This phenomenon is frequently seen during showers, and at the prow of a boat which is throwing up spray. The results of experiments by Professor Osborne Reynolds show that the surface of water upon which these drops are maintained must be clean. Owing to the great surface tension of water scum is generally found floating upon it. If flower of sulphur is scattered upon the surface and then removed by suitable means, the scum is carried with the sulphur and the water is left clean. Upon this cleaned surface drops of water float about for some time. These drops are entirely confined to the surface which is clear. The temperature or condition of the air do not appear to affect the phenomena.—*Literary and Phil. Society, Manchester*, Oct. 4, 1881.—*Nature*, Nov. 3, 1881. J. T.

3. *Photometric investigation of the absorption of light.*—C. Pulfrich employed Vierordt's spectro-photometer and also Glans's instrument for this investigation, and gives a number of curves which indicate the relation between what is termed the extinction coefficient and the absorption constants of the substances examined. The variations of these relations under different conditions are discussed; and Ketteler's formula which expresses the relation between refraction coefficients, extinction coefficients and wave lengths is examined experimentally.—*Annalen der Physik und Chemie*, No. 10, 1881, p. 177. J. T.

4. *Density of the Earth.*—Ph. v. Jolly has employed the balance to directly determine the density of the earth. A body was weighed in two stations distant 21·005^{m} vertically from each other. The errors incident to this method were examined and the value obtained for the earth's density was $\rho=5·692$. The results obtained by previous observers are as follows:

Maskelyne	4·713
Cavendish	5·48
Reich	5·58
F. Baily	5·66
A. Cornu and J. B. Baille	5·56
Carlini	4·837
Airy	5·480

—*Annalen der Physik und Chemie*, No. 10, 1881, p. 331. J. T.

5. *On a new arrangement for sensitive flames*; by Lord Rayleigh.—A jet of coal gas from a pin-hole burner rises vertically in the interior of a cavity from which the air is excluded. It then passes into a brass tube a few inches long, and on reaching the top, burns in the open air. The front wall of the cavity is formed of a flexible membrane of tissue paper, through which external sounds can reach the burner.

The principle is the same as that of Barry's flame described by Tyndall. In both cases the *unignited* part of the jet is the sensitive agent, and the flame is only an indicator. Barry's flame may be made very sensitive to sound, but it is open to the objection of liability to disturbance by the slightest draught. A few years since Mr. Ridout proposed to enclose the jet in a tube air-tight at the bottom, and to ignite it only on arrival at the top of this tube. In this case, however, external vibrations have very imperfect access to the sensitive part of the jet, and when they reach it they are of the wrong quality, having but little motion transverse to the direction of the jet. The arrangement now exhibited combines very satisfactorily sensitiveness to sound, and insensitiveness to wind, and it requires no higher pressure than that of ordinary gas-pipes. If the extreme of sensitiveness be aimed at, the gas pressure must be adjusted until the jet is on the point of flaring without sound.

The apparatus exhibited was made in Prof. Stuart's workshop. An adjustment for directing the jet exactly up the middle of the brass tube is found necessary, and some advantage is gained by contracting the tube somewhat at the place of ignition.—*Cambridge Phil. Soc.*, Nov. 8, 1880.

6. *On an effect of vibrations upon a suspended disc*; by Lord Rayleigh.—In the British Association experiment for determining the unit of electrical resistance, a magnet and mirror are enclosed in a wooden box, attached to the lower end of a tube through which the silk suspension fiber passes. Under these circumstances it is found that the slightest tap with the finger-nail upon the box deflects the mirror to an extraordinary degree. The disturbance appears to be due to aerial vibrations within the box, acting upon the mirror. We know that a flat body, like a mirror, tends to

set itself across the direction of any steady current of the fluid in which it is immersed, and we may fairly suppose that an effect of the same character will follow from an alternating current. At the moment of the tap upon the box the air inside is made to move past the mirror, and probably executes several vibrations. While these vibrations last, the mirror is subject to a twisting force tending to set it at right angles to the direction of the vibration. The whole action being over in a time very small compared with that of the free vibrations of the magnet and mirror, the observed effect is as if an impulse had been given to the suspended parts.

The experiment shown is intended to illustrate this effect. A small disc of paper, about the size of a sixpence, is hung by a fine silk fiber across the mouth of a resonator of pitch 128. When a sound of this pitch is excited, there is a powerful rush of air in and out of the resonator, and the disc sets itself promptly across the passage. A fork of pitch 128 may be held near the resonator, but it is better to use a second resonator at a little distance in order to avoid any possible disturbance due to the neighborhood of the vibrating prongs.—*Cambridge Phil. Soc.*, Nov. 8, 1880.

7. *Edison's Electrical Meters.*—A recent number (Nov. 23), of the excellent electrical Journal "La Lumière Électrique," contains a description by the scientific editor, M. Th. Du Moncel, of two forms of meters designed by Mr. Edison to measure the amount of electricity consumed in a given case either for mechanical purposes or for lighting. One of these is very simple in construction, but requires that a weighing operation should be performed each time it is desired to learn the amount of electricity which has been consumed; the other is somewhat more complicated, but accomplishes all its results automatically, making a record on a dial after the manner of ordinary gas meters.

The first of these consists of two closed copper sulphate voltameters placed in separate adjoining compartments of the enclosing case; to one of these the subscriber is supposed to have access and the other is to be used for verification by the officer of the company which supplies the electricity. The electrodes in each cell are formed of copper plates placed near to each other so that as the current passes a deposit of copper is made on one of them by the electrolytic action. The current passing through the voltameters is a branch of the main current which is being used, and by means of a small resistance coil its intensity is reduced to a small fraction, perhaps one one-hundredth, of it. The use of the instrument is as follows: When the current passes in the main circuit to effect its work, either mechanically or in illumination, a certain known portion of it traverses the two voltameters and causes in them a deposit of copper which is proportional to the given current in the given time. As the exact relation between the intensity of the current which traverses the voltameters to the main current is known, it is easy to deduce the quantity of electricity which has been used from the amount of copper deposited on the negative electrode; the weight of copper

is obtained whenever desired by removing the electrode and weighing it. As a supplementary arrangement, designed to remove all danger of the freezing of the liquid in the voltameter, a metallic thermometer is placed beneath, so adjusted that when the temperature falls near the freezing point a second branch current is sent through an incandescent lamp and the heat thus produced is sufficient to accomplish the end named.

The second form of electrical meter cannot be intelligibly described in all its ingenious details without reference to the figure which accompanies the original article, but the main principle is not complex. It consists of two voltameters each placed beneath one end of the beam of a balance. The cells are filled with saturated copper sulphate and in each there is a fixed cylindrical electrode of copper and fitting within it a similar electrode but movable, being suspended from the beam of the balance above. The arrangement of the current is such that these electrodes play alternately the parts of electrodes of solution and of reduction. As the current passes there results, consequently, first an increase of weight of one movable electrode from the deposit of copper, and a loss of weight of the other, and this causes a deflection of the beam of the balance. A counterpoise suspended by a slender vertical rod, from the center of the moving beam, is thus moved to one side until contact is made with an electro-magnet, and by means of an oscillating lever the current is reversed. In consequence of this change the respective gain and loss of weight of the movable electrodes are also reversed, and corresponding to this the balance beam regains its horizontal position and is then deflected to the other side. This continues until, as before, the movement of the counterpoise causes another reversal of the current, and so on. By means of the same oscillating lever which, by its connection with the suspended counterpoise, brings about the reversal in the current at the proper moment, each deflection of the balance beam is registered on a dial plate, and as the relation between the current in use and that passing through the voltameters is exactly known, and as the weight of copper which must be deposited on the movable electrode in order to bring about one swing of the balance (determined by the weight of the counterpoise) is also known, it is easy to deduce the amount of electricity which has been used from the readings of the dial plate.

8. *On the Carbonic acid in Sea-water*; by Hercules Tornöe. (The Norwegian North Atlantic Expedition of 1876–1878. Chemistry, pp. 24–44).—The early determinations of the amount of carbonic acid in sea-water show a very wide variation. For example, Frémy gives 2·2 to 2·8 c. c. to the liter of surface water; Pisani gives 6·0 to 8·1 c. c.; while by a somewhat different process Bischof obtained 39·0 c. c. and Vogel 55·6 to 116·3 c. c. In these earlier experiments the carbonic acid was driven off by boiling under the normal pressure, and the amount thus collected was assumed to have been present free as gas or, to a small extent, combined in bicarbonates. In the later determinations,

made in connection with the "Pommerania" Expedition of 1871, in which the gaseous elements in the water were boiled out at a very low temperature under diminished pressure, it was found that the quantity of carbonic acid expelled was small; moreover, when the same sample of water was again boiled the results obtained were very variable. Jacobsen was led by these results to investigate anew the absorptive capacity of sea-water for carbonic acid. He determined the amount contained in the water of the North Sea to be about 100 mgr. per liter, and of this he concluded that only a very small proportion was obtained from the bicarbonates; and further he was confident that no portion of the neutral carbonates was decomposed by the boiling process. He found, however, that even when the boiling process was carried on under the full atmospheric pressure the carbonic acid, though supposed to exist in the gaseous form, escaped so slowly that concentration to about one-tenth of the original volume was needed to obtain it all. To account for this phenomenon Jacobsen ascribed to sea-water a peculiar power of retaining its carbonic acid depending, as he believed, upon the magnesium chloride present. This hypothesis was adopted by J. Y. Buchanan, chemist of the "Challenger" Expedition, who also, as the result of a series of experiments, concluded further that most of the salts present in sea-water had this property of retaining the carbonic acid, but most of all the sulphates. He, accordingly, in his determinations first precipitated the sulphuric acid by barium chloride, but otherwise adopted the method of Jacobsen. The amount of carbonic acid in the water of the Southern Seas he found to be 43·26 mgr. per liter.

The conclusions which have been described were, however, questioned by Törnöe, of the Norwegian North Atlantic Expedition, and his experiments lead to a very different result. Considering it more probable that the carbonic acid obtained was derived from the decomposition by the protracted process of boiling of the neutral carbonates present, than that it existed as a gas and was retained under the peculiar conditions supposed, he carried on a series of experiments to decide this point. Two hundred c. c. of sea-water were distilled nearly to dryness and the carbonic acid collected in baryta water; 20·2 mgr. were found to have been driven off. Freshly boiled water was now poured on the residue and it then evaporated, the result yielding only a trace of carbonic acid; finally some purified and freshly-heated soda was added, and the whole again diluted to the original volume. As soon now as the boiling commenced, the carbonic acid was liberated in quantities so large that part passed unabsorbed through the baryta water. The experiment was also repeated with precipitated calcium carbonate, and the carbonic acid expelled from it in considerable quantities, though not so large as before. These results prove beyond question that the earlier methods of determining the free carbonic acid in sea-water were inaccurate, inasmuch as the boiling process causes a decomposition of the neutral

carbonates. In the autumn of 1878 the experiments of Tornöe were again resumed, after an interval of about a year. By the use of an improved form of apparatus devised by Classen, the total amount of carbonic acid yielded by sea-water on boiling was determined, and found to agree very closely with that obtained by Jacobsen's method. The determinations were, however, carried still further, and not only the total amount measured but also that portion present in combination with neutral carbonates, and the difference between the two gave the amount combined with bicarbonates, for it is shown that the earlier observations can only be explained in case the water contains no free gas. Tornöe gives a table in which the results of seventy-eight determinations, made with water taken between 65° and 80° N. latitude, from various depths, from the surface down to 1861 fathoms. The table shows a remarkable constancy in results, the amount of carbonic acid forming carbonates varying from 48·4 to 54·7 mgr. per liter, and that forming bicarbonates from 39·7 to 48 mgr. If a few exceptional observations made on water taken from points near the ice on the coast of Greenland are excluded, the extreme variations are only 4 mgr. and 8 mgr. respectively. As the average result, the amount of carbonic acid forming neutral carbonates is found to be

$$52{\cdot}78 \pm 0{\cdot}083 \text{ mgr.}$$

per liter, with a probable error for a single observation of 0·662 mgr., and for that forming bicarbonates

$$43{\cdot}64 \pm 0{\cdot}16 \text{ mgr.}$$

with a probable error of 1·26 mgrs. per liter. A series of experiments were also carried on to explain the liberation of gas from the carbonates on boiling, and the conclusion is reached that this is due to the slow reciprocal action of the carbonates and salts of magnesia it contains. In regard to the character of the carbonates present in sea-water, Tornöe believes it probable that they are rather sodium and potassium carbonates than carbonate of calcium, this supposition serving to explain the alkaline reaction of sea-water noted by him, and also the resistance to decomposition observed, allowing of their being exposed for an hour together to a temperature of nearly 90° C. without effect. Earlier determinations of the amount of carbonates present have given in some cases none, in others only traces, and in others as much as 0·3 gr. per liter. This variation is explained by the fact, which will be clear from what has preceded, that the methods employed were not such as to allow of even approximate accuracy.

9. *On the Action of the Oxides of Nitrogen on Glass at a high temperature*; by Thos. M. Morgan.—Several attempts were made to determine the nitrogen in organic nitro-derivatives by heating the substance in sealed tubes of hard glass containing oxygen, and in presence also of a little mercury to effect the reduction of any oxides of nitrogen which might be formed, but in all cases the nitrogen obtained was considerably less than the

quantity theoretically present in the substance analysed. The source of this deficiency was eventually traced to the action which the oxides of nitrogen exerted on the alkali of the glass, and also on the mercury. For when some of the tubes which had been subjected to a temperature not above dull redness were washed with a little water, the washings could always be shown to contain a nitrate and a soluble salt of mercury; others, the temperature of which had been higher, contained nitrates and nitrites, but no soluble mercury salt.

For the purpose of showing more conclusively that the glass was thus attacked, and in order also to investigate the extent of the action, the following experiment was performed: A tube of hard glass, 50 c. c. capacity, was cleaned until the evaporated washings left no appreciable residue. A quantity of oxygen was next introduced, and then so much nitric oxide that the tube was filled with red fumes; after which it was heated to dull redness for two hours. When cold it was still full of red fumes, and when these were withdrawn it was washed as before, and the evaporated washings left a residue of 0·0038 of a grm., consisting of nitrates and nitrites The same experiment was repeated three times on the same tube; the second residue was 0·0044 of a grm., and the third 0·0022. Another tube gave 0·0048.

As might be expected, this action is much more energetic at a high than at a low temperature, and it appears to be very slight until the heat approaches redness. In the analysis of such nitrogenous compounds as have the nitrogen in combination with oxygen, a certain deficiency of nitrogen, varying with the temperature employed, may therefore be expected.—*Chem. News*, *Nov.* 25, 1881.

II. Geology and Mineralogy.

1. *On the Periodical Variations of Glaciers.*—Mr. F. A. Forel, of Morges, has an important memoir on this subject in the Geneva Archives des Sciences Physiques et Naturelles, July, 1881, based on observations in the Alps. He refers to the great elongation of the Grindelwald glacier in 1593, that of the Bossons in 1817, of the Gorner glacier in 1857, and also of the remarkable shortening of the Grindelwald glacier in 1540 and of the large Swiss glaciers generally in recent times, and seeks to ascertain the cause of the changes. The following is a brief review of his argument.

The length of a glacier varies, beyond doubt, with (1) the supply of snows, and (2) the melting of the ice or *ablation* by means of heat. Abundant snows lengthen it; heat thins and shortens it. The shortening by heat in summers, or the supplies of snow in the winters immediately preceding, have been referred to as the chief cause of variation. But observations show that glaciers lengthen during cold summers, when the snows are not sufficient to account for the change. The true theory was sug-

gested in 1821 by Venetz, and fully propounded in 1831 by F. J. Hugi, the able professor of Soleur. The points are these:—

(1.) *The law of long periodicity.*—Glaciers vary by long periods—five, ten, twenty years or more, not by annual changes. The Pfarrbuch of Grindelwald, from 1575 to 1602, underwent great elongation; from 1602 to 1620, was stationary; from 1665 to 1680, shortened; in 1703, reached its maximum elongation; in 1720, reached a maximum retreat, and in 1743, a maximum elongation; in 1748, again made a maximum retreat; in 1770 to 1778, lengthened; in 1819, became much elongated, and in 1840 was still advancing; but from 1855 to 1880, has had a period of retreat.

(2.) *The law of variation contained in the law of retreat.*—In 1870 and 1871, Dufour and Forel, when studying the condensation of the moisture of the air on the glacier of the Rhone and the evaporation of the ice, were struck with the fact of the very evident retreat of this great glacier. From observed facts by Ph. Gosset and his aids, of the Swiss Alpine Club, it has been found that from 1857 to 1870 the retreat was 23 meters a year; from 1870 to 1874 the retreat was 71 meters a year; and from 1874 to 1880 the retreat was 41 meters a year. Thus, through 24 years, retreat has been going on with no year of advance. So, also, the glacier des Bois was in retreat from 1854 to 1875; that of the Bossons from 1854 to 1875, and the upper glaciers of Grindelwald have continued to retreat since 1855.

The facts connected with the Rhone sustain the conclusion that—

The determining factor in the variations of length in glaciers is not ablation, but the rate of onward movement in the ice.—The flow of the ice-stream acts conjointly with the melting. The latter is a consequence of annual changes and therefore is irregular and of rapid action, and hence cannot be the cause of the long periodicity exemplified in the glacier of the Rhone. The former depends on changes of long periodicity in meteorological conditions—heat, moisture, winds.

In the 24 years, from 1857 to 1880, there were 15 years in which the mean temperature of the summer was above the normal, and 9 years in which it was below; 16 years in which the mean for the year was above the average, and 8 in which below; and these numbers were for the absolute humidity, 14, 10, and 16, 8; and for precipitation, 14, 10, and 12, 12. Thus the long-period condition was one that should have produced a retreat; the diminished flow of the glacier was the great factor and must be so for all cases. Ablation does an important part of the work, but is subordinate to the rate of flow.

Small variations in the thickness of a glacier in its upper part toward its source, produce large changes in the movement below. Augmented thickness above produces more rapid movement, and consequently a less long exposure to ablation, and thereby less loss in ice; and the reverse for diminished thickness. The gla-

cier when shortening, loses also in its other dimensions. There is internal ablation as well as external—interstitial fusion taking place between the grains of the glacier and ablation along the walls of crevasses; and this action, besides being one of the means by which the thinning takes places, causes loss of movement, the amount of which diminishes upward along the glacier. Moreover, the greater the thickness the less proportionally is there of this internal ablation. Internal ablation tends then to exaggerate the small variations in the rate of flow, and produces great effects in the inferior part of the glacier, although small above.

The variations in the amount of snows, which cause the greater thickness of the glacier at its source, depend on long terms of periodicity. The precipitation at Geneva was below the normal (88159^{mm}) from 1835 to 1841 inclusive; above it, 1842 to 1857; near the normal in 1858 to 1861; below it in 1862 to 1877; above since 1877. It is seen that there is an approximate parallelism between these changes and the variations in the glaciers of the Alps. The effects are not immediate, as should be expected, but follow more or less closely the greater meteorological movements.

It is seldom that all the glaciers of the Alps, without any exception, lengthen or shorten together. In this century, the only case of simultaneous elongation took place in the year 1817 and 1818, and the only one of general retreat in 1872 to 1874. During the years 1812 to 1836, most of the glaciers underwent a shortening; but the Bois, Unteraar, and Gorner glaciers continued for some years their movement of elongation. The period of shortening which included the above-mentioned years, 1872–1874, commenced in Mont Blanc about 1854; in the Upper Grindelwald, in 1855; the Giétroz, in 1855; the Rhone, in 1857; the Aletsch, in 1860; the Gorner, in 1870; the Fiesch, in 1870; the Unteraar, in 1871; and it ended with the Bossons about 1875; with the Bois, in 1879; the Trient, in 1879; the Giétroz, in 1880. The facts seem to show that it took twenty years after the cycle of retreat began for the time of *simultaneous* retreat to arrive.

Hugi, besides giving the above explanations, illustrates them by reference to the same class of facts, though of less range of years.

With regard to the coming on of the conditions of the Glacial period in the Alps, the author attributes the result chiefly to a gradual, but feeble, augmentation in the annual fall of snow depending on slight changes in hygrometric conditions, connected with a series of moist and mild winters and moist and cold summers, as was long since suggested by Professor Guyot. The increase in the snows thickens the ice, quickens movement, widens the area of the névé, unites glaciers before separate and thus quickens the rate of flow through a diminution of friction; causes an increase of snows and a general cooling of the climate; makes new glacier areas, and tends thus to augment all the above-mentioned effects.

But M. Forel adds, while these effects would follow in mountain regions like the Alps, other regions, as the Vosges, the Cé-

vennes, the mountains of Scotland, etc., which are now remarkable for the amount of rain, show that increase in humidity is not the only cause needed to bring on a Glacial era; it is necessary also for such countries that there should have been a general lowering of the temperature of Europe.

2. *On the Movement of Glaciers.*—The observations made by Messrs. Koch and Klocke in 1879, on the Morteratsch glacier in Eastern Switzerland to determine the rate and character of its movement have already been described in this Journal (xix, 425). The same observers in the following year (Sept., 1880) made a second series of similar measurements, using essentially the same methods as before. It will be remembered that their first observations seemed to prove a considerable and unexpected degree of irregularity in the movement. It was found, for example, that the same point could have a motion in both a vertical and horizontal direction, and that two points not very far apart, in some cases, moved at a different rate or even in opposite directions. The observations of 1880 have, on the whole, given a rather negative result since, for some unknown reason, the motions measured were much smaller than before, those in a vertical direction, for example, hardly exceeding the unavoidable errors of observations. The authors state in detail their improved methods and the means taken to eliminate the errors, and finally give tables showing the results of their measurements during two or three days out of the fourteen over which the series extended. They conclude that the amount of observed movement, vertical and horizontal, often did not exceed the probable error, and hence their results do not allow of satisfactory discussion, but that they, notwithstanding, indicate real ice movements, and are not to be referred to irregularities in the position of the observing telescope. — *Wied. Ann.*, 1881.

3. *On Soilcap-Motion*; by R. W. Coppinger, Esq., M. D.—I wish to call attention briefly to a phenomenon which, so far as I am aware, exists to an unparalleled degree about the shores of Western Patagonia, and whose presence there is in a great measure due to the exceptionally wet nature of the climate. I allude to a slippage of the soilcap, which is, I believe, continually taking place over the basement rock wherever the latter presents a moderately inclined surface. Some of the effects of this soilcap-motion are apt to be confounded with those due to glacial action; for the soilcap takes with it in its progress not only its clothing of trees, ferns, and mosses, but also a "moraine profonde" of rocks, stones, stems of dead trees, peat and mud, whereby the hills of this region are being denuded, and the valleys, lakes and channels, gradually filled up.

On arriving at the Patagonian archipelago my attention was directed to this subject on noticing that the lower branches of trees fringing the sea-shore were in many places withering from immersion in the salt water, and that in some cases entire trees had perished prematurely from their roots becoming entirely sub-

merged. On looking more closely I observed that the sodden snags of dead timber, mingled with stones, were often to be seen at the bottom of the inshore waters, and that the beds of fresh-water lakes were plentifully strewn with similar fragments of wood, the remains of forests prematurely destroyed. As the soilcap, by its sliding motion, reaches the water, the soluble portions are removed; and just as stones and bowlders are often seen deposited in grotesque situations by a melting iceberg or a receding glacier, so are the phenomena of "perched rocks" to be here observed, although, in the class of cases to which I refer, due to a totally different cause. These facts are all the more interesting from their occurring in a region where the effects of *old* glacial action are to be seen in a marked degree. Planings, scorings, striæ and "roches moutonnées" may almost invariably be found wherever the rock is sufficiently capable of resisting the disintegrating influence of the weather to retain these impressions. Thus they are nowhere to be seen on the coarse-grained, friable syenite, which is the common rock-formation of the district; but where this rock is intersected by dikes of the more durable greenstone, the above-mentioned signs of former glacial action may be seen well developed. There are therefore in this region ample opportunities of comparing and differentiating phenomena which have resulted from "glacial action" and those which are due to "soil-cap-motion"—a force now in active operation.

I may here observe that we did not see any glaciers worthy of the name either on the western islands or abutting on the mainland shores of Patagonian channels, although they undoubtedly exist farther eastward, and discharge icebergs at the head of some of the deep fiords. In the main straits of Magellan there are fine examples of complete and incomplete glaciers, where may be observed, in all its grandeur, the wonderful denuding power which these ponderous masses of ice exercise as they move silently along their rocky beds.

Sir Wyville Thomson (vide 'Voyage of the Challenger,' the "Atlantic," vol. ii, p. 245) attributes the celebrated "stone rivers" of the Falkland Islands to the transporting action of the soilcap, which, among other causes, derives its motion from expansion and contraction of the spongy mass, due to varying conditions of moisture and comparative dryness; and this hypothesis is to a certain extent supported by the occurrences which I am now endeavoring to describe. Here, in Western Patagonia, are evergreen forests, and a dense undergrowth of brushwood and mosses clothes the hillsides to a height of about 1000 feet; and this mass of vegetation, with its subjacent soil, resting as it frequently does upon a hillside already planed by ice-action, naturally tends, under the influence of gravitation, combined with that of expansion and contraction, to slide gradually downward until it meets the sea or a lake or valley. In the first two cases its free edge is then removed by the action of the water, in a manner somewhat analogous to the wasting of the submerged snout of a Greenland glacier in the summer time; and in the last case the valley becomes converted into a deep morass.

It appears to me that the conditions which are said to have resulted in the production of the "stone rivers" of the Falklands here exist in equal if not greater force. There is the thick, spongy, vegetable mass covering the hillsides and acted on by varying conditions of extreme moisture and comparative dryness; there are the loose blocks of disintegrating syenite to be transported; and there are the mountain-torrents, lakes and sea-channels to remove the soil. Of actual motion of the soilcap we have at least strong presumptive evidence; but nowhere in the valleys have I found anything resembling a "stone river."

It might perhaps be thought that a slow and gradual depression of the land would account for some of the above phenomena; but I have seen no reliable sign whatever of *subsidence*, and have, on the contrary, the evidence of numerous raised beaches and the work of the stone-boring mollusca at heights above the present sea-level to prove that *elevation* of the land has taken place.

The subject is one full of interest; and feeling confident that it will repay further investigation.—*Quart. J. Geol. Soc.*, 1881, 348.

4. *Evaporation and eccentricity as co-factors in Glacial periods.*—Rev. E. Hill discusses this subject in a paper published in the Geological Magazine, viii, p. 481, November, 1881. He observes that the capacity of air for aqueous vapor increases with the temperature, but in a rapidly increasing ratio; and accordingly the absolute quantity of vapor required to saturate a given volume of air at different temperatures varies much more widely than do the temperatures. A consequence of this relation is, that if two volumes of saturated air of different temperatures are mingled, precipitation must occur. For example, a cubic meter of air at 10° C. and 20° C. would contain, respectively, 9·83 and 17·19 grams, or an aggregate of 26·57 grams of vapor; but when mingled, the mixture would assume the mean temperature of 15° C., and could then contain but 25·54 grams of vapor. Conversely, the capacity for vapor of two cubic meters of dry air at different temperatures is greater than that of a similar aggregate volume at the mean of these temperatures. Hence, since the rate of evaporation is dependent on the capacity for vapor of the air above the water, it follows that *the mean evaporation under varying temperatures exceeds the evaporation at the mean temperature*; and, moreover, *when temperatures vary about a mean, increased variation produces increased evaporation.* A high degree of eccentricity in the terrestrial orbit increases the annual range in temperature, and accordingly augments the total evaporation, and hence, also, the precipitation; and since the heat absorbed in evaporation is taken from the earth's surface, while that given out in condensation is lost high in the atmosphere, it is manifest that the total loss of heat by the earth must be increased.

These considerations support Croll's view of the relation between high eccentricity and glacial periods. Though this effect of evaporation is here clearly recognized for the first time, it is among the agencies whose combined influence was

empirically computed by the writer in the December number of this Journal. W. J. MCGEE.

5. *Report on the Geological and Natural History Survey of Minnesota for* 1880; N. H. WINCHELL, State Geologist. 392 pp. 8vo, with vi plates. St. Peter, 1881.—This new volume contains detailed Reports on the Forestry of Minnesota by O. E. GARRISON; on the geography and hydrology of the Upper Mississippi by C. M. TERRY; and on the Glacial phenomena of the State and the region some distance north and west by WARREN UPHAM; also a descriptive list of rocks, descriptions of three new Lower Silurian Brachiopods (two of Orthis and one of Strophomena), and a note on the Cupriferous series by Prof. WINCHELL; a list of the birds of Minnesota by Dr. P. L. HATCH; and a note on an ancient outlet of Lake Manitoba by H. S. TREHERNE.

The report on the hydrology treats of the rivers and lakes and other features with much detail. It states among its facts, that the lakes, of which there are several thousand, are gradually diminishing in extent and depth, or drying up, and attributes the change that is going on chiefly to cultivation. The rain waters which formerly made streamlets over the grassy prairie, and thus reached the lakes, now fall on ploughed soil and are absorbed. The records at Fort Snelling since 1836 show as yet no evidence of change in amount of rain. The profuse growth of water plants also tends to fill them. They often have low ridges of gravel and stones along the shore, which were made by the pushing action of ice when freezing, and also by transportation shoreward when the lakes are flooded. An excellent map (Pl. V) illustrates this report.

Mr. Upham's account of Glacial phenomena is devoted largely to the courses of terminal moraines and is full of interest. The facts are presented also on a map, on which the courses of the moraines, and the supposed direction of movement of the glacier are laid down. The courses of Glacial striæ in different parts of the State are given in a table as well as on the map, and indicate wide variations, the limits being S. 60° E. and S. 60° W. The map represents the outline of the moraine as extending from the Mississippi, between the meridians of 93° and 94°, south to the parallel of 41½°, and then as trending northwestward with some westing to the Coteau des Prairies whose course it follows. West of this range, according to information derived from different sources, the moraine bends southward in latitude 45½° and continuing to latitude 43° (or nearly to the Missouri) between the meridians of 97° and 98° making a second prolongation or lobe which has the Coteau du Missouri along its western side. The drift sheet is stated to be 100 to 200 feet thick over the western two-thirds of Minnesota —and the material is for the most part an unstratified mixture of earth, stones and clay. The color below is usually dark bluish.

The drift contains stones of Archæan rocks from north of Lake Superior, occasional masses of native copper from the vicinity of the same lake, and limestone bowlders probably from Manitoba; and some of the Archæan in the till south and west of Minnesota

were probably transported 500 to 700 miles. The following general statement of Mr. Upham's conclusion is from an early page of his report:

"The terminal moraines, which form the principal subject of this report, show that the southern portion of the continental ice-sheet was divided into great lobes, each having a central current in the direction of its longer axis, with diverging currents bending from this and becoming perpendicular to its border. The red and blue till were the deposits of two such ice-lobes which overspread Minnesota from the northeast and northwest. During the most severe epoch of the ice age, before that in which the terminal moraines of Minnesota were accumulated, an ice-sheet reached much farther south, to a limit 20 to 100 miles southwest and south of the Missouri river and within a less distance north of the Ohio river. Portions of this glacial sheet, moving from the northeast, north, and northwest, enclosed an area about 150 miles long from north to south and 100 miles wide, lying principally in southwestern Wisconsin, but extending into Illinois, Iowa and southeastern Minnesota, which was not covered by ice and has no till nor striæ. This driftless area has a less average height than the adjoining regions which were glaciated. Climatic conditions of greater snow-fall and lower temperature seem to have produced the ice-fields, which lay at each side of this tract and were confluent farther south. The wedge-shaped area of highland that reaches southwest from Keweenaw Point, at the south side of Lake Superior, and the depressions of Lake Michigan and Lake Superior, have also been regarded as the causes of this division of the continental glacier.

The occurrence of this driftless tract shows that the ice-sheet which reached farthest south was divided in portions that moved independently, with diverging and converging currents; and that in respect to the districts over which they extended, these glacial movements corresponded to the lobes that formed the southern part of the ice-sheet at the later time when the looped moraines of Wisconsin, Minnesota, Iowa and Dakota were pushed out at its margin."

6. *On joints or diaclases intersecting the stratified rocks in the vicinity of Paris;* by M. Daubrée, (Bull. Soc. Géol. de France, June, 1880).—This very interesting paper contains details as to the two directions of joints or fractures, nearly at right angles with one another, which exist at the various quarries in Tertiary and Cretaceous strata about Paris. M. Daubrée points out the system in their courses, and the exceptional directions, and also their general parallelism to the reliefs of the region (the most prominent being parallel to the outcrops of the Chalk and the valley of the Seine) illustrating the same by a map; and he remarks on the perfect conformity to the results of his experiments making fractures, by pressure and torsion described in his great work on Experimental Geology.*

* See also, for a notice of these experiments, Dana's Manual of Geology, edition of 1880, pages 801, 832.

7. *Brick-clays making cream-colored bricks in Minnesota.*—Professor N. H. WINCHELL, in Miscellaneous Publications, No. 8 of the Geological Survey of Minnesota, states that the clays of many localities in Minnesota (among them Brainerd, Minneapolis, Carver, Chaska and Jordan), afford on burning cream-colored brick, and a few, brick of a dirty drab or ash-gray. The clay is described as an *alkaline* clay, and like the related clay of Milwaukee, partially fuses therefore in the baking, so that the iron present (which may be as much as in other clays) enters into combination with the silica and alumina instead of remaining as oxide, a point first explained by Mr. E. T. Sweet. These alkaline clays are those of the earlier drift, and are supposed by Professor Winchell to have been derived from the clay-beds of the Cretaceous. The clay-beds in the State connected with the later alluvium make red brick.

8. *Geology of Frenchman's Bay, Maine, just east of Mount Desert Island.*—This locality is the subject of a paper by W. O. CROSBY in the Proceedings of the Boston Society of Natural History, 1880, p. 109. The schistose rocks of the region about Frenchman's Bay are an obscurely crystalline mica schist, quartzite, siliceous argillite, sometimes hornblendic; and the group is metalliferous, it containing the silver-bearing vein at Sullivan Falls. These rocks are stated to occur on the north side of Frenchman's Bay and to be part of an extensive formation bordering the coast at intervals from the Penobscot to New Brunswick. On the islands of the bay are other rocks, referred to a later age, which are entirely unerystalline, the chief kind being a slate of black, drab and purplish shades of color, passing into siliceous slate and sandstone and a micaceous slate. They contain no fossils in Frenchman's Bay, but the same slate on the southwest side of Hawthorne Island, afforded Mr. Crosby markings resembling the *Palæochorda minima* of Emmons; and a similar slate has afforded at Narraguagus, according to Professor E. S. Hitchcock, an *Orthis* and *Crinoidal joints*, and at Foster's Island off Machiasport, undetermined *Rhynchonellæ*. Mr. Crosby agrees with Professor Hitchcock in referring the slate rocks of Frenchman's Bay, probably to the Cambrian or Primordial. The rocks of the region are intersected by dikes of diorite or allied rocks and granite.

9. *Coking coal and anthracite of Colorado.*—Professor J. S. NEWBERRY, in the Transactions of the New York Academy of Sciences, for 1881–1882, p. 8, observes that a coking coal occurs within twenty-five miles of Crested Butte of special excellence, it being firm, not affected by the weather, and containing but little ash and sulphur. The region borders on a volcanic area, and the coal is from the part of the basin which has mostly escaped alteration by volcanic heat. He remarks also that the anthracite, of Anthracite Creek, according to a recent analysis made at the School of Mines, New York, contains less than one per cent of sulphur, and only three of ash and is not inferior to Pennsylvania anthracite.

10. *Copper-bearing region in Northern Texas and the Indian Territory.*—The geology of this region is briefly described by J. H. Furman, in the Trans. N. Y. Acad. Sci. for 1881–1882 (p. 16). The copper ore occurs in shale overlaid by gypsiferous sandstone, the western part of Haskell County, Texas, and is found as nuggets of copper ore, stains of malachite, and wood fossilized more or less completely with copper ore. The strata are about horizontal. The ore was found along a band usually less than fifty yards wide, stretching eight to ten miles, to the southern boundary of the county; also five miles farther north, and in Knox and Hardeman Counties, and beyond in the Indian Territory. Professor Newberry added, in the discussion which followed the reading of Mr. Furman's paper, remarks on the similarity of the ores and their mode of occurrence to the same in the upper portion of the Triassic in New Mexico, and southern Utah, and observes that in the localities hitherto explored, the ore is too much scattered to be profitably mined. The wood, impregnated with the ore and also that which occurred silicified, he said was undoubtedly Coniferous of the Araucarian family, as he had found from a microscopic examination.

11. *The Amygdaloid of Brighton, Massachusetts*, has been examined microscopically by Dr. E. R. Benton, and pronounced to be a true eruptive rock. A paper on the subject, accompanied by a map, is contained in the Proceedings of the Boston Society of Natural History, vol. xx, 416, 1880.

12. *Primordial Trilobites in Sardinia.*—Prof. Meneghini has announced the discovery of new species of trilobites in slaty and arenaceous beds at Gutturu Sergiu in Nebida, Sardinia, which he names *Paradoxides Gennari* (near *P. Bohemicus* in size), *P. armatus*, *P. Bornemanni*, and *Conocephalites Bornemanni.*—*Atti Accad. d. Lincei*, 1881, p. 306.

13. *Journal of the Cincinnati Society of Natural History*, Vol. IV, No. 1.—Contains descriptions of new Crinoids and other fossils of the Hudson River group, and notice of *Strotocrinus Bloomfieldensis* by S. A. Miller (with a plate); descriptions of new fossils of the Lower Silurian and Subcarboniferous rocks of Ohio and Kentucky by A. G. Wetherby (with a plate); on new species of Entomostraca by V. T. Chambers.

14. *Fossils of the Cincinnati Rocks.*—The "Paleontologist" of Cincinnati, edited by U. P. James, contains a notice of *Scolithus linearis* from the Cincinnati group, in the eastern part of Cincinnati; of three species of *Monticulipora* supposed to be new; of *Dekaya maculata* James; of eight species of *Ptilodictya;* and of an *Orthis* and two species of *Streptorhynchus.*

15. *Volcanoes: what they are and what they teach*; by John W. Judd, F.R.S. (Kegan Paul and Co.: London, 1881.)—This work forms volume xxxv of the International Scientific Series. In his earlier studies the author enjoyed the counsel and assistance of Mr. Poulet Scrope, who up to his death was an eminent authority on volcanoes, and the present book may in some sense be regarded as continuing the work of that pioneer in Vulcanology.

In Chapter I the nature of the inquiry in hand is stated and reference made to the older investigators, Spallanzani, Dolomieu and Scrope. Chapter II deals with the nature of volcanic action, illustrated by the ordinary phenomena of Stromboli and by the eruption of Vesuvius in 1872, and in each case the action is attributed to the elastic force of confined steam. Chapter III describes the characteristics, chemical, mineralogical, and microscopical, of the lavas, while Chapter IV discusses the other ejected materials, scoria, pumice, etc., as also the change of form in volcanoes resulting from ejections of lava and scoria, illustrating by Monte Neuvo, and by the history of changes in the cone of Vesuvius itself.

In Chapter V the internal structure is described, as shown in the Kammerbühl in Bohemia, in Vulcanello and in the volcanic wrecks of the islands of Mull and Skye. In this connection the method of formation of a cone from scoria is experimentally illustrated by the mode of deposition of saw-dust blown vertically from an orifice in a horizontal plane; and the formation from viscid lava, by soft plaster forced through a similar opening, as devised by Dr. E. Reyer. In Chapter VI the author discusses the structures built up about the vents, the cones of scoria, tufa or lava and their varying forms, the parasitic cones formed by lateral openings along fissures in the sides of the main cone, the change of position of the vent along such fissures, the crater-rings and lakes, mud-volcanoes, etc.

Chapter VII gives the life history of the volcano, detailing the probable order of the phenomena, from the first issue of the steam and gases from the rent in the earth's crust, through the eruption of andesitic and trachytic lavas, to the basaltic or basic lavas, the building of the cone, the intrusion of lavas between the adjacent strata forming laccolites, and across the strata forming dikes, the appearance at first of the acid gases at high temperatures, and later when the temperature has fallen, of sulphuretted hydrogen and carbonic acid, and finally of hot water in geysers or springs, until all manifestation of igneous agency disappears and the cycle is complete.

Chapter VIII speaks of the distribution of volcanoes; that of the 300 or 350 active volcanoes, the majority on islands, arranged in lines thousands of miles long, and all near the sea except two or three in Central Asia. And it may be stated here, that advices more recent than the work of which we are writing would indicate that these apparent exceptions in Asia are not really volcanic but are due to beds of coal and petroleum which have become ignited in former years. (See Dr. A. Regel in *Petermann's Mitth.*, vol. xxvii, 10, 1881, p. 384, also General Kolpakofsky, *Nature*, Oct. 27, 1881.)

Chapter IX infers that the volcanic action of earlier geological ages was both in its nature and in its products similar to that of our own day. Chapter X illustrates the part played by volcanoes in the economy of nature, by the growth of the Alpine chain.

Chapter XI discusses the probable condition of the earth's inte-

rior, and Chapter XII the causes of volcanic action, stating at length the several theories advanced by different authorities on these points, but without being able to reach any perfectly satisfactory conclusion. The author favors a solid rather than a molten nucleus within the earth, and would attribute the volcanic action in general to high temperature joined with abundance of vapors and gases beneath the volcanic vent; but no new theory is offered to account for the occurrence of these conditions within the crust of the earth.

The book is illustrated with numerous diagrams and wood cuts and will well repay the general reader, as well as those who are more especially interested in Vulcanology. It is a fair presentation, so far as its limits allow, of the present state of knowledge and opinion in that department of science. C. G. R.

Princeton, Nov. 26, 1881.

16. *Mineralogical Notes;* by EDO CLAASSEN.—(1.) *Analysis of orthoclase* from Ishpeming, Marquette County, Michigan. (Communicated.)—The orthoclase occurs in crystals on hematite, the so-called No. 10 ore of the Cleveland Iron Mining Company. The crystals are small and sometimes single, but mostly in twins. They are often united in bundles. The single crystals form four-sided prisms with oblique terminations. The measurement of the angles, which could not be done very exactly on account of the curved planes, by the common goniometer, showed that these planes were I and $2\text{-}i = (\infty P, 2P\infty)$. Hardness of the crystals about 6; color, white, reddish and red. They dissolved in no acid except hydrofluoric acid, but were easily decomposed by fusion with the carbonates of sodium and potassium. Although the greatest care was taken to get the crystals for the analysis in a pure state, a magnifying lens still shows a few very small particles of the ore remaining with them, so that in the analysis below the amount of Fe_2O_3 should be somewhat diminished. It is evident that an analysis of the perfectly white crystals would not afford any iron. The reddish and red crystals contain—

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	H_2O
63·712	17·546	1·644	0·714	0·172	13·807	0·233	0·612	0·606 = 99·046

The P_2O_5 in another sample amounted to 0·685 per cent.

(2.) *On regular polyhedral cavities in hematite.* Some time ago I observed several specimens of micaceous hematite, from the Lake Superior iron region, containing cavities from one-eighth to three-quarters of an inch in diameter. An exact examination showed them to be bounded by five-sided planes similar to those of the pentagonal dodecahedron of pyrite. By the measurement of their angles it was put beyond doubt that these cavities once contained crystals of pyrite. Access of air and water had evidently effected their disappearance. Not the smallest particle of this mineral, however, could be met with either in these cavities or in any other part of the ore.

Cleveland, Ohio, November, 1881.

17. *Analysis of the Emerald-green Spodumene from North Carolina;* by F. A. GENTH.—The following analysis of the Alexander County spodumene (*hiddenite*) was furnished by Dr. Genth, and should have been added to the article on the crystalline form of the species on page 179 of the last volume, but was not received in time. The presence of a small quantity of chromium shown by this analysis is interesting as bearing upon the question as to the cause of the color to which this variety of spodumene owes its beauty:

SiO_2	Al_2O_3	Cr_2O_3	FeO	Li_2O	Na_2O	K_2O
63·95	26·58	0·18	1·11	6·82	1·54	0·07=100·25

Specific gravity = 3·177.

18. *New Mineralogical Works—Lehrbuch der Mineralogie von* Dr. GUSTAV TSCHERMAK. Erste Lieferung. 192 pp. 8vo. Vienna, 1881 (Alfred Hölder).—The new work of Professor Tschermak promises to be a most important addition to the small number of mineralogical text-books of the higher grade which represent the present state of the science in all its departments. The first part, now published, which will form about one-third of the completed volume, contains the Crystallography and the larger portion of the Physical Mineralogy. The author presents the subject from the advanced point to which the science has reached through the rapid progress made during the past few years. The book is throughout an original one, to a limited extent necessarily in the topics discussed, but fully so as regards the way in which old principles are presented. The style is clear and concise, and the author's long experience as a teacher has given him an unusual power in explaining difficult subjects in an intelligible and attractive form.

Materialien zur Mineralogie Russlands von N. von Kokscharof. Volume viii, pp. 33–320. St. Petersburg, 1881.—The first portion of volume eight of the valuable work by Professor Kokscharof on Russian Mineralogy was issued about three years since (this Journal, xvii, 486, 1879). The continuation, now received, contains more or less extended notices of the following species: perofskite, epidote, æschynite, phosgenite, bournonite, greenockite, quartz, samarskite, amphibole, beryl, magnetite, pyroxene, vanadinite, jarosite, sulphur, garnet. Descriptions of the crystals of various artificial compounds are also given. The memoirs contained in the volumes of this series will always be regarded as models of careful and accurate crystallographic work.

Elemente der Mineralogie von Carl Friedrich Naumann, elfte vollständige neu bearbeitete und ergänzte Auflage von Ferdinand Zirkel, 735 pp. 8vo. Leipzig, 1881 (Wm. Engelmann).—The appearance of a new edition of the long known and always valued Mineralogy of Naumann is an event deserving of notice. This edition, the eleventh, has been prepared, as was the preceding (this Journal, xiv, 424, 1877), by Professor Zirkel, of Leipzig. The new matter added gives the more important results of mineralogical investigations during the past four years. It speaks

well for the position which this work holds, that it is possible for the publishers to reprint the entire volume after so comparatively short an interval.

Mineral Karakteristik: En handledning vid bestämmandet af Mineralier och Bergarter af Dr. F. J. Wiik. 217 pp. small 8vo. Helsingfors, 1881.—This little volume will doubtless receive the welcome it deserves among the special class of students and readers for whom it is intended. It ranks with the well known works on Determinative Mineralogy: for example, those of Weisbach and Websky on the physical side, and of von Kobell and Brush on the chemical side. Professor Wiik devotes the first part of the volume to a general discussion of the crystallographical, physical and chemical character of minerals; the remainder contains brief descriptions of the more important mineral species arranged in three independent systems: first, according to the crystalline form; second, according to the physical characters, luster, color, hardness and specific gravity; third, according to the chemical characters as given chiefly by the blowpipe. The idea of drawing out independently each of these three methods of determining minerals, and of giving under each those characters of the mineral which belong there, is for purposes of instruction an excellent one.

III. Botany and Zoology.

1. *A Manual of the Coniferæ, containing a general Review of the Order, a Synopsis of the hardy kinds cultivated in Great Britain, their place and use in Horticulture, etc., etc.* James Veitch & Sons, Royal Exotic Nursery, King's Road, Chelsea. 1881. pp. 343, roy. 8vo.—We have had the pleasure to receive this large and beautiful volume, the most popular book of the day upon Coniferous trees, as it is the most recent. It is well adapted to its purpose, which is not to serve as a scientific treatise, but to supply the demand for practical information which is constantly made upon an establishment like that of the Messrs. Veitch, and, indeed, is made by the legions of planters of Conifers in Great Britain and elsewhere. It is copiously illustrated by wood engravings, the smaller ones in the letter-press, the larger as separate plates. Among the most notable of the latter, that of a branch and cone (nine inches long) of *Abies nobilis*, grown at Bicton, takes the lead; a view of the famous *Araucaria*-avenue at Bicton faces the title-page; the unrivalled *Araucaria* at Dropmore (now sixty-one feet high and in the most perfect condition) is represented from a photograph specially taken for the purpose; and hardly less interesting are such as the *Taxodium* on the bank of the Thames at Syon House—the lower part only represented, surrounded for sixty feet on all sides with a thick growth of 'knees,' emulating a "cypress swamp" in Carolina; also Earl Ducie's fine *Abies bracteata* at Tortworth, a fir which, wherever it can be healthfully grown "will always be regarded with genuine admiration."

A. G.

2. *Repertorium Annuum Literaturæ Botanicæ Periodicæ, curavit* G. C. W. Bohnenzieg, Custos Bibliothecæ Societatis Teylerianæ. Tom. vi. Haarlem. pp. 420, 8vo.—This most laborious and painstaking work has gone on to the sixth volume, systematically cataloguing the botanical articles in current periodicals. This volume, issued in the year 1881, deals with the articles which were published in the year 1877, in 237 different periodicals.

A. G.

3. *Jahrbuch des Königlichen Botanischen Gartens und des Botanischen Museums zu Berlin*; herausgegeben von Dr. A. W. Eichler. Band I. Berlin, 1881, 8vo, 351, tab. vi.—A new botanical periodical, in the form of an annual volume, intended especially to represent the work done by the accomplished director and others at the Berlin Botanic Garden and Museum. Naturally it will be more devoted to systematic and phænogamous botany than is common in the German journals of the present day; and, as is fitting, the Linnæa will be merged in it.

The form is royal octavo, paper and print excellent, and the type Roman. A proper commencement is the opening article which fills almost half the volume, in which, after a brief statement by Professor Eichler of the condition and operations of the Berlin Botanic Garden and Museum, including the Herbarium, during the three years of his direction, the complete history of these establishments is given by Dr. Urban, the assistant director of the garden. Three plates exhibit ground plans of the garden, in 1801, in 1812, and 1881, and a photographic front view of the museum building, which has just been erected at a cost of about $175,000. The annual cost of maintaining the garden, including the museum, is about $17,500. The present Prussian government is more liberal to it than was the first king Frederic William, who upon its establishment as a real botanical garden, ordered that, in view of the great regard he had for the learning and merits of the Royal Berlin Society of Sciences, that learned society should maintain the garden out of its own scanty funds.

Dr. Eichler has articles upon Inflorescence-bulblets; upon Heterogeneous shoots; upon the nature of the Vine-stem as to its morphology; upon Cephalotus-pitchers; Gareke, a synopsis of *Paronia* (in which *P. Leontei* is kept distinct from *P. hastata*, though it seems to be only a waif of that South American species); G. Ruhmer, an article upon wild and cultivated Thuringian hybrids; Urban, on the pollenization of *Lobeliaceæ*, with a monograph of *Monopsis*; F. C. Dietrich, a biography of the collector Sieber, with an enumeration of his distributed collections, and a list of names to the numbers (645) of his Herbarium Floræ Novæ Hollandiæ; Potonié describes the Anatomy of the Lenticels of *Marattiaceæ*, the stomatic apparatus of Ferns, etc.; Ascherson has an article on the subfloral axis as apparatus for dissemination, as in *Stipa*, *Erodium*, *Podopterus*, *Brunnichia*, etc.; and in a note he characterizes a new African *Brunnichia*, the same probably as one which has been or is about to be figured in the Icones Planta-

rum at Kew. Finally, Kuhn gives a synopsis of the species of *Adiantum*, 113 species. A. G.

4. ENGLER'S *Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie* is well kept up. In November the fourth fasciculus of the second volume was published (Leipzig, Engelmann), continuing the systematic digest of botanical publications—whether works or articles—in the year 1881, and also containing four original articles. A. G.

5. HOOKER'S *Icones Plantarum*, part III of the fourth volume of the third series, or the fourteenth volume of the entire work,—issued in October, 1881—is most interesting for its figures of Grasses, in which some of the work in the Genera Plantarum is anticipated. There is a plate in which some of our botanists may recognize the *Lepturus paniculatus* of Nuttall. Mr. Bentham has ascertained that it is not of this genus, nor much related to it. And he has also found a published name for it, *Schænonurdus Texanus*, of Steudel, who, however, had no idea that he had to do with Nuttall's plant. The information we here give will not be gathered from the work before us; for the letter-press for this plate 1360 has inadvertently been omitted. *Munroa squarrosa*, Torr., and *Dissanthelium Californicum* are other North American Grasses, the latter being the rare *Stenochlon Californica* of Nuttall, which proves to belong to a South American genus founded by Presl. A. G.

6. *Occurrence of an additional specimen of Architeuthis at Newfoundland;* by A. E. VERRILL.—This specimen (No. 27) was taken at Portugal Cove, near St. John's, Newfoundland, November 10, 1881. This example was nearly perfect and was shipped to New York, packed in ice, on the steamer "Catima," Capt. Davies. In an article in the New York Herald, of November 25th, the following measurements of the fresh specimen were given, on the authority of Inspector Murphy, chief of the Board of Public Works Department: Length of body, 5·5 feet; length of the head, 1·25 feet; total length, to end of tentacular arms, 28 feet; circumference of body, 4·5 feet. A photograph of this example was made by Mr. E. Lyons, of St. John's, and a cut copied from this has been published in Harper's Weekly, for December 10, 1881.

This specimen was purchased by Mr. E. M. Worth and preserved in alcohol at his museum, 101 Bowery street, New York, where, through the courtesy of Mr. Worth, I have recently had an excellent opportunity for a satisfactory examination. Although a valuable specimen, it is not in all respects perfect, for the tips of all the sessile arms are broken off, and many of the suckers are gone; one-half of the caudal fin had apparently been lost and the wound healed some time before the creature's death; the eye-balls had been burst in handling, and the pen mostly destroyed. But notwithstanding these defects, this specimen is more nearly perfect than any that has been previously brought to this country, and has, therefore, afforded me important information in respect

to several of the organs that have not been preserved in any other specimen. Of these points the following may be mentioned: The siphon is large, with the aperture slightly bilabiate, and four inches broad; valve large; dorsal bridles well-developed; siphon-pit broad, not very deep, *smooth;* eye-lids large, only slightly angulated and thickened, with a shallow sinus; diameter of opening, 4·5 inches; transverse nuchal crest, back of eyes, evident, but not much elevated; one longitudinal crest, on each side, short and not much raised, the others apparently rudimentary, possibly rubbed off. The median dorsal angle of the mantle-edge is rather prominent; lateral angles evident; lateral connective cartilages of the mantle very simple, consisting only of a short, simple, longitudinal ridge; connective cartilages on the base of the siphon simple, long-ovate, somewhat oblique, slightly concave. Anterior tip of the pen very thin, broad, obtuse. The caudal fin was too much mutilated before and after death to afford additional information. When examined by me, after it had been in alcohol about two weeks, the body measured 4·16 feet in length, along the side; length of head, 1·25 feet; circumference of body, 4 feet; of sessile arms, 7·5 to 8·5 inches; length of ventral arms, minus tips, 4·66 feet; of tentacular arms, 15·5 feet.

7. *Descriptions of some new and rare Cephalopoda. Part II.*<*Trans. Zool. Soc. London, xi, part* 5, *pp.* 131–170, *pl.* 23–35, *June,* 1881. By Richard Owen.—This important paper is of special interest on account of the figures and descriptions that it contains of two gigantic species.

Under the new name, *Enoploteuthis Cookii*,* Professor Owen has described in detail, and has given excellent figures of most of the existing parts of this large and remarkable cephalopod, which have been so long preserved in the Museum of the College of Surgeons, and have often been referred to, but hitherto have never been scientifically described, (see Ceph. N. E. Am., p. 241).† It is to be regretted, however, that Professor Owen has neither described nor figured the dentition of the radula, in a manner to enable it to be used as a systematic character. His statement in regard to it is of the most general kind, and shows only that there are seven rows of teeth. It is also a matter of

* The synonymy of this species is as follows:

Enoploteuthis Cookii Owen.

Trans. Zool. Soc. London. xi. p. 150, pl. 30, figs. 1–3; pl. 31, figs. 1–4; pl. 32, figs. 1–6, pl. 33, fig. 1, (restoration), June, 1881.

Seppia angiculata Molina, 1810 (no description).

Enoploteuthis Molinæ D'Orbigny, Ceph. Acétab., p. 339, 1845–1848.

? *Enoploteuthis Hartingii* Verrill, this vol., p 241, pl. 24, figs. 4–4*b*, 1880.

† In referring in this notice to my own work upon Cephalopods, I have made all the references to my paper in Trans. Conn Acad., v, on "The Cephalopods of the Northeastern Coast of America." Of this, Part I (80 pp., 14 pl.), relating to the large species, was published December, 1879 to March, 1880. A still more detailed report by me on the same subject is contained in the report of the U. S. Fish Commission for 1879, not yet issued. Many of the statements and descriptions quoted are also contained in several of my former articles in this Journal.

surprise that he has not compared any of the portions that he describes with the corresponding parts of the equally large and very closely allied *Enoploteuthis*, carefully described and figured by Harting in 1861 (see Ceph. N. E. Am., p. 240), and to which I gave, in 1880, the well-merited name, *Hartingii*. It is not improbable that the two forms are really identical, but this cannot be certainly determined from the figures, because the corresponding parts are not always represented in the same position, and it is uncertain whether the corresponding arm is preserved in the two cases. Harting figures, rather poorly, the teeth of the radula, which appear to be very peculiar, if his figure is correct, (see my pl. xxiv, fig. 4*b*). The shape of the mandibles appears to be different in the two species, however, and the large hooks differ in form.

Professor Owen has also given a somewhat detailed description, with figures, of the large cephalopod-arm, long preserved in the British Museum. But this had previously been pretty fully described by Mr. Saville Kent, in 1874, whose description has been quoted by me (see Ceph. N. E. Am., pp. 241–242). Professor Owen, like Mr. Kent, fails to state to which pair of arms the specimen belongs. This is a very important omission, for in *Architeuthis*, as in most other genera, the arms belonging to different pairs differ in form and structure. The describers of this arm would doubtless have been able to ascertain to which pair it belonged by a direct comparison with the arms of *Ommastrephes*, or any other related genus.

For this arm, Professor Owen endeavors to establish a new genus and species (*Plectoteuthis grandis*). The genus is based mainly on the fact that there is a marginal crest along each outer angle, and a narrow, protective membrane along each side of the sucker-bearing face. These peculiarities are precisely those seen in the *ventral arms* of *Architeuthis*, and have already been described by me in former articles (see Ceph. N. E. Amer., p. 214), as found in *A. princeps*. Similar membranes or crests are found on the *dorsal* arms of *Sthenoteuthis pteropus* and other related species. The protective or marginal membranes outside of the suckers are found in many allied genera.

The suckers on the arm, as described and figured by Professor Owen, are exactly like those of *Architeuthis*. Therefore, there is no ground whatever for referring this arm *to any other genus*, and *Plectoteuthis* must become a synonym of *Architeuthis*.

Whether the arm in question belongs to a species distinct from those already named, I am unable to say. There is, apparently, nothing to base *specific* characters upon, except the form of the suckers and of their horny rings But the description of the horny rings is not sufficiently precise, nor the figures sufficiently detailed, to afford such characters. If the arm is one of the ventral pair, as seems probable, the suckers as figured by Professor Owen, and especially as more fully described by Mr. Kent, agree closely, but not perfectly, with those of the Newfoundland specimens; in the

latter the sucker-rings of the ventral arms are at most only slightly denticulated on the inner side, and most of them are entire on that side. But they also agree well with those of the *Architeuthis Hartingii*, as figured by Harting. Those of the original *A. dux* Steenst., have neither been described nor figured. As this arm cannot, at present, be referred with certainty to any of the named species, it may be best to record it as *Architeuthis grandis*, until better known.

In the same article, Professor Owen has given a good figure (pl. 33, fig. 2), of the tentacular arm of the Newfoundland specimen (my No. 2), copied from the same photograph described by me (see Ceph. N. E. Am., pp. 181, 182, 208, 209). To this he applies the name, *Architeuthis princeps*,* without giving any reason for not adopting my conclusion that it belongs to *A. Harveyi*. But he does not, in any way, refer to the latter species, although he mentions the specimen (my No. 5), or rather the photograph of the specimen, on which that species was based. He apparently (on p. 162), supposes that both photographs and Mr. Harvey's two series of measurements refer to the same specimen, which is by no means the case, as had been sufficiently explained by me, in several former papers.†

The brief account, given by Professor Owen, of the large Cephalopods described by others includes none additional to those noticed in my report. On the other hand he omits those described by Harting; those described by Mr. Kirk, from New Zealand; and several others.

Professor Owen has given a description and colored figure of a cephalopod without locality, under the name of *Ommastrephes ensifer*, for which he proposes the subgeneric name *Xiphoteuthis*. The latter name is, however, preoccupied by Huxley. His species is a typical example of my genus *Sthenoteuthis* (1880) and appears to be identical in every respect with *S. pteropus* (see Ceph. N. E. Amer., pp. 228–233, pl. 55, figs. 2, 2*a* and pl. 36, figs. 5–9), from Bermuda. But Professor Owen fails to mention one of the most characteristic features of this group of squids, viz., the connective tubercles and smooth suckers on the proximal part of the tentacular club, nor is his figure sufficiently detailed to indicate this char-

* By a singular mistake, Professor Owen, on p. 163, states that this species was named *A. princeps* by Dr. Packard, in February, 1873. But according to his own statement on p. 161, the specimen was not actually obtained till December, 1873, *at least nine months after Dr. Packard's article was printed*. In truth, the name *princeps* was first given by me in 1875, to designate a pair of very large jaws. Neither this nor any other name appears on the cited page of Dr. Packard's article, though he elsewhere referred the same jaws doubtfully to *A. monachus*.

† It seems incredible that Professor Owen could have made these mistakes, had he actually examined either of my former papers, in which these specimens (with several others), have been described in detail with many figures, not only from the photographs, but from the preserved specimens also. He does, however, refer to my paper in the Trans. Conn. Acad., vol. v. But as he states (p. 162) that in it "a brief notice is given of Mr. Harvey's squid," it is fair to suppose that the reference is taken at second-hand, for it is not to be supposed that he would have considered sixteen pages of text, accompanied by five plates, a "*brief notice*."

acter, nor even the actual arrangement and structure of the other suckers of the club. The high median crests and broad marginal webs of the 3d pair of arms are well shown, but these are about equally broad in *S. pteropus* and *S. megaptera*, and are also present in all the related species of this group.

Owen's specimen had a total length of 3 feet; length of body, 15 inches; of head to base of dorsal arms, 3·7; of 3d pair of arms, 12; of tentacular arms, 21; breadth of caudal fin, 12·6; length of their attached bases, 6·6; breadth of body, 5; length of 1st, 2d, 3d, 4th pairs of arms, 8·9, 11, 12, and 9·6 inches respectively. The specimen is a female. It agrees very closely in size with the Bermuda specimen described by me, and its proportions do not differ more than is usual with alcoholic specimens of any species preserved under different circumstances, and in alcohol of different strength. The original specimen of *S. megaptera* V., is considerably larger.

A handsome squid from the China Sea, is described as *Loligopsis ocellata*, sp. nov. (p. 139, pl. 26, figs. 3–8, pl. 27). This is evidently not a true *Loligopsis*, but belongs, in all probability, to my genus *Calliteuthis* (1880). It agrees very closely, even to the coloration, and the form of the fins and pen, with my *C. reversa*, but differs in having serrate suckers. This species should, therefore, be called *Calliteuthis ocellata*. The genus probably belongs to the Chiroteuthidæ. It is much larger than my specimen, but, like the latter, it had lost the tentacular arms.

The remaining species described are as follows: *Triteuthopus cornutus*, gen. et sp. nov., a large Australian octopod, with three rows of suckers; *Sepia palmata*, nov., Australia; *Sepioteuthis brevis*, nov., Japan; *Sepiola Oweniana* D'Orb., anatomy; *Onychoteuthis raptor*, nov.

A. E. VERRILL.

8. *The Zoology of H. M. S. Challenger, Part IX. Report on the Echinoidea*; by ALEXANDER AGASSIZ. 4to. 321 pp., 65 plates. 1881.—In this elaborate and very valuable report the author not only describes in detail and handsomely and profusely illustrates the numerous new forms collected by the Challenger, but also gives a very valuable review of the known facts in respect to the geographical and bathymetrical distribution of all the known living echini, and their relations to those of the Jurassic, Cretaceous* and Tertiary ages. The first nineteen pages are devoted to classification and to special features in the structure of echini,—especially the plates, spines, and pedicellariæ. Several plates are also devoted to these structural features. Among the large number of new and strange forms dredged in the deep seas, the two families most conspicuous on account of their unusual characters and forms, and their numbers, both in species and individuals, are the *Echinothuridæ* and the *Pourtalesiæ*. Of the former group, three genera and twelve species are here described. Some of these are of large size, and all have flexible shells, with more

*The chapter on the relation of the existing and the Cretaceous forms has been reprinted in this number (see p. 40).

or less imbricated plates. In the general account of this group its possible relationship with the Palæozoic echini is discussed, in a very suggestive way. Of the curious *Pourtalesiæ*, seven genera and thirteen species (12 new) are described, all of them from deep water, and nearly all from the southern hemisphere.

The total number of species enumerated from this collection is 139, of which 52 species and 15 genera were new. The total number of existing species included in the geographical lists is 297, belonging to 107 genera. This is an increase of 90 species and 25 genera over those included in the author's Revision of Echini (1872–4). Of the whole number, 201 known species are regarded as "littoral," occurring in less than 100 fathoms, though some of these (36 species) range to much greater depths; 46 are regarded as "continental," ranging mainly from 100 to 450 fathoms in depth, though 10 of these also go down to much greater depths; of true "abyssal or oceanic" species, 50 are enumerated, most of them ranging below 350 fathoms, often to 1000 fathoms, 12 descending even to more than 2000 fathoms; but these oceanic species are also associated with 10 littoral and 14 continental species, some of which also extend to great depths. The greatest depth from which Echini were dredged by the Challenger was 2900 fathoms. A. E. V.

9. *On the Geographical Distribution of certain fresh-water Mollusks of North America, and the probable causes of their variations*; by A. G. Wetherby, A.M. Journal Cincinnati Soc. Nat. Hist., Jan. 1881.—Professor Wetherby here gives the facts, gathered from a wide range of observation, respecting the distribution of certain groups of fresh-water Mollusks in American waters—the *Unionidæ* and *Strepomatidæ*, with reference to conclusions as to the origin of the species to be presented in another paper. The principal points brought out are as follows:

No species of the *Strepomatidæ* and but few of the *Unionidæ* occur in New England; and the latter, so occurring, are species of many varietal forms found elsewhere on the Atlantic slope; a few of them only having a wide westward and southward range. One New England species, *Margaritana margaritifera* Lamk., also European, is wanting across the whole interior of the continent, but exists in the drainage of the Pacific slope.

The *Strepomatidæ* occur west of the Green Mountains, and are divisible into two geographical groups, a western and a southern.

The *Unionidæ* of the Ohio drainage area, include about a tenth of all described North American species, being 82 in number, of which 70 are species of *Unio*, 17 of *Margaritana*, and 5 of *Anodonta*; these Ohio types extend north of this stream to the limits of the Mississippi drainage, and south and southwestward to Western Texas; while the *Strepomatidæ* are few over this area.

New species of *Unionidæ* and new genera and species of *Strepomatidæ* appear on crossing the Ohio and going south. The new forms begin to appear in Kentucky and continue

through Tennessee to the southern and eastern limits of the Ohio drainage. The facies of the groups of species which this part of the Ohio drainage contains stamps them as of a different fauna from those north.

The Alabama drainage area is anomalous, it affording 184 species, according to describers—but half of which, however, are anything more than varieties. Two genera, of 30 described species, are not found elsewhere — *Schizostoma* and *Tulostoma*; and these kinds, with the peculiar species of *Goniobasis*, belong to a different fauna from many of the Unionidæ associated with them. The region contains the *Unio spinosus*, in the Altamaha River.

The only other spinous Unio, *U. collinus*, occurs in New River, Virginia, on the western slope of the Appalachians, far to the north.

Some of the species never present any varieties that could be taken for distinct species. This is true, among the Ohio types, of *U. tuberculatus*, *U. cylindricus*, *U. irroratus*, *U. anodontoides*, *U. cornutus*, *U. rectus*, *U. triangularis*, *Margitana dehiscens*, and others. Many other species are exceedingly variant and have led to the naming of many so-called species that are only varieties.

The facts in the second part of this important paper will be published in the following number of this Journal.

IV. Astronomy.

1. *Elements of Comet VII*, 1881 (*Swift*).—Professor Boss of the Dudley Observatory has computed the following elements of Comet VII, 1881 (Swift), from observations made by him on November 20, 28 and December 10.

$T = 1881$, November 17·41 Washington Time.
$\omega = 116^\circ\ 30'$
$\Omega = 180\ \ 59$
$i = 144\ \ 58$
$\log q = 0{\cdot}2841$

This comet is remarkable for its great perihelion distance. The following Ephemeris may be of service, in case the comet does not prove too faint for observation.

Ephemeris for Washington, midnight.

1882.	α	δ	log Δ.	Brightness.
Jan. 7	$23^h\ 37^m\ 36^s$	$+20^\circ\ 07'$	0·3050	·31
11	38 43	+18 19	0·3265	·28
15	40 15	+16 44	0·3469	·25
23	43 52	+14 07	0·3843	·20
31	48 00	+12 04	0·4171	·17

Brightness November 20 taken as unity. x.

2. *The Longitude of Morrison Observatory, Glasgow, Mo.*; by Professor J. R. Eastman, U. S. N., and Professor H. S. Pritchett, Astronomer at Morrison Observatory, now of Washington Uni-

versity, St. Louis. 15 pp. 4to. Washington, 1881. (Washington Observations for 1877. Appendix V.)—By means of a series of electric signals, exchanged between the Observatory at Washington and the Morrison Observatory, at Glasgow, Mo., it has been determined that the transit circle of the latter observatory is $1^h\ 3^m\ 5^s{\cdot}926$ west of the central dome of the United States Naval Observatory.

V. Miscellaneous Scientific Intelligence.

1. *Annual Report of the Chief Signal Officer of the Army to the Secretary of War for the year* 1881. 86 pp. 8vo. Washington, 1881.—The Report of General Hazen is very satisfactory as showing that under his control the United States Signal Service is not only to be kept up to the high standard which was maintained under the late General Myers, but is to be made more efficient both in its practical bearings and still more from a scientific point of view. The report details the numerous respects in which progress has been made, and in which it is promised in the future. These include various details of the service, such as the establishment of a permanent school of instruction at Fort Myers, Va.; the raising of the standard of the *personnel* of the Signal Corps; the systematization of the duties of the Service; the preparation of new instructions for observers, and many improvements in the publication of information for the benefit of the public in the various ways in which changes in the weather may affect their interests in the different parts of the country, as in "river warnings," "frost warnings" for the cotton States, special bulletins in regard to tornadoes, "cold and hot waves," and so on.

From a scientific point of view, the most important advances which are being made in the Signal Service, and those which promise most for the future, are in connection with what is called the "Scientific and Study Division," and which has for its object the research and investigation into the laws of meteorology. This division has been placed in charge of Professor Abbe, and under him three gentlemen have been appointed upon examination —viz: Messrs. Winslow Upton, H. A. Hazen and Frank Waldo—who are to act as expert mathematicians and "computers."

In connection with this division a number of "Consulting Specialists" have been selected to whom strictly scientific questions will be submitted—as those concerning the staindard barometer and thermometer, pendulum apparatus and observations, atmospheric absorption of solar heat, ground electrical currents and atmospheric electricity, chemical analysis of air, collection and examination of atmospheric dust. In addition, a Committee of Conference was appointed by the National Academy at the Washington meeting, April 17, consisting of nine prominent scientific men to whom "the Chief Signal Officer may refer, as occasion arises, questions of meteorological science and its applications." Of special scientific investigations undertaken in connection with

the Signal Service and promising important results may be mentioned the expedition of Professor Langley to Mount Whitney during the past season, to study the absorption of the sun's heat by the atmosphere. The Signal Service has also taken up the important subject of standard time, to which reference has been made in this Journal (vol. xxi, p. 414). Finally, General Hazen mentions what has been done by the Service in coöperation with the International Committee of Polar Research, which has, during the past two years, organized a system of stations in both Arctic and Antarctic regions. At these stations observations will be conducted hourly and bi-hourly, in meteorology, magnetism and tides, with special observations on gravity, auroras, earth currents, etc. The knowledge thus gained will be invaluable in affording data for the solution of many obscure meteorological problems. The stations established by the United States are at Lady Franklin Bay, 81° 40′ N. lat., 64° 30′ W. long., and at Point Barrow, Alaska, 71° 27′ N. lat., and 156° 15′ W. long.

2. *National Academy of Science, Nov.*, 1881.—The following are the titles of papers entered.

On a Gigantic Salpa found in the Gulf Stream, A. Agassiz.

The Echini of the Challenger Expedition, A. Agassiz.

The Distribution of Corals of the Tortugas, A. Agassiz.

The Porpitidæ, the Velellidæ, and the Surface Fauna of the Gulf Stream, A. Agassiz.

Classification of the Dinosauria, O. C. Marsh.

Succession in Time of the Allotheria, O. C. Marsh.

On Complex Inorganic Acids, W. Gibbs.

On the Theory of the Dynamo-electric Machine, W. Gibbs.

Mean annual rain-fall for different countries of the Globe, E. Loomis.

On the Phenacodontidæ, a new group of Perissodactyla, E. D. Cope.

A comparison between the shells of Kjökkenmöddings and present shells of the same species, E. S. Morse.

On the Objects and Results of the Recent Expedition to Mt. Whitney, S. P. Langley.

On a form of regulator for driving-clock of an Equatorial, C. A. Young.

On the Logic of Number, C. S. Peirce.

Statement respecting experiments on the Velocity of Light, S. Newcomb.

Notice of a remarkable mineral vein in the Black Range (Negretta Mts.) of Socorro County, New Mexico, B. Silliman.

Facts regarding Sorghum and some conclusions as to its value as a source of sugar, P. Collier.

On a new form of Volumescope, R. E. Rogers.

On Mascart's electrometer and its use as a Meteorological instrument, G. F. Barker.

On Hydrometer Scales, C. F. Chandler.

On Chinoline; its Synthesis and Medical uses, H. Morton.

On the Fossil and Recent Faunæ of the Oregon desert, E. D. Cope.

Biographical Memoir of the late Professor S. S. Haldeman, J. P. Lesley.

Newly determined line of the Terminal Moraine across Pennsylvania, J. P. Lesley.

An Elementary Treatise on Electricity, by JAMES CLERK MAXWELL, M.A.; edited by WILLIAM GARNETT, M.A. 208 pp. 8vo, with 6 plates. Oxford, 1881. (Clarendon Press.)

Tables of Qualitative Analysis, arranged by H. G. MADAN, M.A., F.C.S. 20 pp. 4to. Oxford, 1881. (Clarendon Press.)

OBITUARY.

Mr. ROBERT MALLET, F.R.S., long known for his valuable memoirs on earthquakes and volcanoes, died on the fifth of November, at the age of seventy-one. Mr. Mallett was born in Dublin on June 3, 1810. He qualified himself early in life as an engineer, and for a number of years was actively engaged in the work of his profession. His taste for scientific study led him also to spend much time in study and research, and in 1846 his first paper on earthquake phenomena was published in the Philosophical Magazine. Two years later he published, in the Transactions of the Royal Irish Academy, a paper containing an exposition of his views on wave-movement in earthquakes, and from that time until the end of his life his scientific activity did not cease, although during his later years he was afflicted with almost total blindness. Altogether he was the author of more than seventy memoirs, besides several separately published works. These memoirs relate for the most part to the phenomena of earthquakes and volcanoes, and will always be of the greatest value to the student of these subjects; in fact the subjects may be said to have been, in many respects, developed by him. Among the more important of his scientific contributions may be mentioned the Earthquake Catalogue completed, with the aid of his son (Professor J. W. Mallet, of Virginia), in 1858; also the memoir containing his observations on the Neapolitan earthquake published in two volumes, in 1862, in which for the first time he laid down the method of studying such phenomena; and still again the paper on Volcanic Energy published in the Transactions of the Royal Society in 1872. The last memoir mentioned contains the results of a series of careful experiments and of calculations based upon them, on the amount of heat produced by the crushing of different kinds of rocks; the conclusions reached, in regard to the probable mechanical source of much of the heat involved in metamorphic action and volcanic phenomena, have exerted a wide influence, and their importance can hardly be overestimated.

(The facts contained in this notice are mostly taken from *Nature* of December 1.)

APPENDIX.

Art. VII.—*Classification of the Dinosauria*; by Professor O. C. Marsh.*

In the May number of the American Journal of Science, (page 423), I presented an outline of a classification of the Jurassic Dinosaurian Reptiles of this country which I had personally examined. The series then investigated is deposited in the Museum of Yale College, and consists of several hundred individuals, many of them well preserved, and representing numerous genera and species. To ascertain how far the classification proposed would apply to the material gathered from wider fields, I have since examined various Dinosaurian remains from other formations of this country, and likewise, during the past summer, have visited most of the museums of Europe that contain important specimens of this group. Although the investigation is not yet completed, I have thought the results already attained of sufficient interest to present to the Academy at this time.

In previous classifications, which were based upon very limited material compared with what is now available, the Dinosaurs were very generally regarded as an order. Various characters were assigned to the group by von Meyer, who applied to it the term *Pachypoda*; by Owen, who subsequently gave the name *Dinosauria*, now in general use; and also by Huxley, who more recently proposed the name *Ornithoscelida*, and who first appreciated the great importance of the group, and the close relation it bears to Birds. The researches of Leidy and Cope in this country, and Hulke, Seeley, and others in Europe, have likewise added much to our knowledge of the subject.

An examination of any considerable portion of the Dinosaurian remains now known will make it evident to any one familiar with reptiles, recent or extinct, that this group should be

* Read before the National Academy of Sciences, at the Philadelphia meeting, November 14, 1881.

regarded, not as an order, but as a sub-class, and this rank is given it in the present communication. The great number of subordinate divisions in the group, and the remarkable diversity among those already discovered indicate that many new forms will yet be found. Even among those now known, there is a much greater difference in size and in osseous structure than in any other sub-class of vertebrates, with the single exception of the placental Mammals. Compared with the Marsupials, living and extinct, the *Dinosauria* show an equal diversity of structure, and variations in size from by far the largest land animals known—fifty or sixty feet long, down to some of the smallest, a few inches only in length.

According to present evidence, the Dinosaurs were confined entirely to the Mesozoic age. They were abundant in the Triassic, culminated in the Jurassic, and continued in diminishing numbers to the end of the Cretaceous period, when they became extinct. The great variety of forms that flourished in the Triassic render it more than probable that some members of the group existed in the Permian period, and their remains may be brought to light at any time.

The Triassic Dinosaurs, although so very numerous, are known to-day mainly from footprints and fragmentary osseous remains. Not more than half a dozen skeletons, at all complete, have been secured from deposits of this period; hence, many of the remains described cannot at present be referred to their appropriate divisions in the group.

From the Jurassic period, however, during which Dinosaurian reptiles reached their zenith in size and numbers, representatives of no less than four well-marked orders are now so well known that different families and genera can be very accurately determined, and almost the entire osseous structure of typical examples, at least, be made out with certainty. The main difficulty at present with the Jurassic Dinosaurs is in ascertaining the affinities of the diminutive forms which appear to approach Birds so closely. These forms were not rare, but their remains hitherto found are mostly fragmentary, and can with difficulty be distinguished from those of Birds, which occur in the same beds. Future discoveries will, without doubt, throw much light upon this point.

Comparatively little is yet known of Cretaceous Dinosaurs, although many have been described from incomplete specimens. All of these appear to have been of large size, but much inferior in this respect to the gigantic forms of the previous period. The remains best preserved show that, before extinction, some members of the group became quite highly specialized.

Regarding the Dinosaurs as a sub-class of the REPTILIA, the forms best known at present may be classified as follows:

SUB-CLASS DINOSAURIA.

Premaxillary bones separate; upper and lower temporal arches; rami of lower jaw united in front by cartilage only; no teeth on palate. Neural arches of vertebræ united to centra by suture; cervical vertebræ numerous; sacral vertebræ coössified. Cervical ribs united to vertebræ by suture or ankylosis; thoracic ribs double-headed. Pelvic bones separate from each other, and from sacrum; ilium prolonged in front of acetabulum; acetabulum formed in part by pubis; ischia meet distally on median line. Fore and hind limbs present, the latter ambulatory and larger than those in front; head of femur at right angles to condyles; tibia with procnemial crest; fibula complete. First row of tarsals composed of astragalus and calcaneum only, which together form the upper portion of ankle joint.

(1.) Order SAUROPODA (Lizard foot.) Herbivorous.

Feet plantigrade, ungulate; five digits in manus and pes; second row of carpals and tarsals unossified. Pubes projecting in front, and united distally by cartilage; no post-pubis. Precaudal vertebræ hollow. Fore and hind limbs nearly equal; limb bones solid. Sternal bones parial. Premaxillaries with teeth.

(1.) Family *Atlantosauridæ.* Anterior vertebræ opisthocœlian. Ischia directed downward, with extremities meeting on median line.

Genera *Atlantosaurus*, *Apatosaurus*, *Brontosaurus*, *Diplodocus*, *? Camarasaurus* (*Amphicœlias*), *? Dystrophæus.*

(2.) Family *Morosauridæ.* Anterior vertebræ opisthocœlian. Ischia directed backward, with sides meeting on median line.

Genus *Morosaurus.*

European forms of this order: *Bothriospondylus*, *Cetiosaurus*, *Chondrosteosaurus*, *Eucamerotus*, *Ornithopsis*, *Pelorosaurus.*

(2.) Order STEGOSAURIA (Plated lizard). Herbivorous.

Feet plantigrade, ungulate; five digits in manus and pes; second row of carpals unossified. Pubes projecting free in front; post-pubis present. Fore limbs very small; locomotion mainly on hind limbs. Vertebræ and limb bones solid. Osseous dermal armor.

(1.) Family *Stegosauridæ.* Vertebræ biconcave. Neural canal in sacrum expanded into large chamber; ischia directed backward, with sides meeting on median line. Astragalus coössified with tibia; metapodials very short.

Genera *Stegosaurus* (*Hypsirhophus*), *Diracodon*, and in Europe *Omosaurus*, Owen.

(2) Family *Scelidosauridæ*. Astragalus not coössified with tibia; metatarsals elongated; four functional digits in pes. Known forms all European.

Genera, *Scelidosaurus*, *Acanthopholis*, *Cratæomus*, *Hylæosaurus*, *Polacanthus*.

(3.) Order ORNITHOPODA (Bird foot). Herbivorous.

Feet digitigrade, five functional digits in manus and three in pes. Pubes projecting free in front; post-pubis present. Vertebræ solid. Fore limbs small; limb bones hollow. Premaxillaries edentulous in front.

(1.) Family *Camptonotidæ*. Clavicles wanting; post-pubis complete.

Genera *Camptonotus*, *Laosaurus*, *Nanosaurus*, and in Europe *Hypsilophodon*.

(2.) Family *Iguanodontidæ*. Clavicles present; post-pubis incomplete. Premaxillaries edentulous. Known forms all European.

Genera *Iguanodon*, *Vectisaurus*.

(3.) Family *Hadrosauridæ*. Teeth in several rows, forming with use a tesselated grinding surface. Anterior vertebræ opisthocœlian.

Genera *Hadrosaurus*, *? Agathaumas*, *Cionodon*.

(4.) Order THEROPODA (Beast foot). Carnivorous.

Feet digitigrade; digits with prehensile claws. Pubes projecting downward, and coössified distally. Vertebræ more or less cavernous. Fore limbs very small; limb bones hollow. Premaxillaries with teeth.

(1.) Family *Megalosauridæ*. Vertebræ biconcave. Pubes slender, and united distally. Astragalus with ascending process. Five digits in manus and four in pes.

Genera *Megalosaurus* (*Poikilopleuron*), from Europe. *Allosaurus*, *Cœlosaurus*, *Creosaurus*, *Dryptosaurus* (*Lælaps*).

(2.) Family *Zanclodontidæ*. Vertebræ biconcave. Pubes broad elongate plates, with anterior margins united. Astragalus without ascending process; five digits in manus and pes. Known forms European.

Genera *Zanclodon*, *? Teratosaurus*.

(3.) Family *Amphisauridæ*. Vertebræ biconcave. Pubes rod-like; five digits in manus and three in pes.

Genera *Amphisaurus* (*Megadactylus*), *? Bathygnathus*, *? Clepsysaurus*; and in Europe, *Palæosaurus*, *Thecodontosaurus*.

(4.) Family *Labrosauridæ.* Anterior vertebræ strongly opisthocœlian, and cavernous. Metatarsals much elongated. Pubes slender, with anterior margins united.

Genus *Labrosaurus.*

Sub-Order Cœluria (Hollow tail.)

(5.) Family *Cœluridæ.* Bones of skeleton pneumatic or hollow. Anterior cervical vertebræ opisthocœlian, remainder bi-concave. Metatarsals very long and slender.

Genus *Cœlurus.*

Sub-Order Compsognatha.

(6.) Family *Compsognathidæ.* Anterior vertebræ opisthocœlian. Three functional digits in manus and pes. Ischia with long symphysis on median line. Only known specimen European.

Genus *Compsognathus.*

DINOSAURIA?

(5.) Order Hallopoda (Leaping foot.) Carnivorous?

Feet digitigrade, unguiculate: three digits in pes; metatarsals greatly elongated; calcaneum much produced backward. Fore limbs very small. Vertebræ and limb bones hollow. Vertebræ biconcave.

Family *Hallopodidæ.*
Genus *Hallopus.*

The five orders defined above, which I had previously established for the reception of the American Jurassic Dinosaurs, appear to be all natural groups, well marked in general from each other. The European Dinosaurs from deposits of corresponding age fall readily into the same divisions, and, in some cases, admirably supplement the series indicated by the American forms. The more important remains from other formations in this country and in Europe, so far as their characters have been made out, may likewise be referred with tolerable certainty to the same orders.

The three orders of Herbivorous Dinosaurs, although widely different in their typical forms, show, as might be expected, indications of approximation in some of their aberrant genera. The *Sauropoda*, for example, with *Atlantosaurus* and *Brontosaurus*, of gigantic size, for their most characteristic members, have in *Morosaurus* a branch leading toward the *Stegosauria.* The latter order, likewise, although its type genus is in many

respects the most strongly marked division of the Dinosaurs, has in *Scelidosaurus* a form with some features pointing strongly toward the *Ornithopoda.*

The Carnivorous *Dinosauria* now best known may all be placed at present in a single order, and this is widely separated from those that include the herbivorous forms. The two sub-orders defined include very aberrant forms, which show many points of resemblance to Mesozoic Birds. Among the more fragmentary remains belonging in this order, but not included in the present classification, this resemblance appears to be carried much farther.

The order *Hallopoda*, which I have here referred to the *Dinosauria*, with doubt, differs from all the known members of that group in having the hind feet especially adapted for leaping, the metatarsals being half as long as the tibia, and the calcaneum produced far backward. This difference in the tarsus, however, is not greater than may be found in a single order of Mammals, and is no more than might be expected in a sub-class of Reptiles.

Among the families included in the present classification, I have retained three named by Huxley (*Scelidosauridæ*, *Iguanodontidæ*, and *Megalosauridæ*),* although their limits as here defined are somewhat different from those first given. The sub-order *Compsognatha*, also, was established by that author in the same memoir, which contains all the more important facts then known in regard to the *Dinosauria.* With the exception of the *Hadrosauridæ*, named by Cope, the other families above described were established by the writer.

The *Amphisauridæ* and the *Zanclodontidæ*, the most generalized families of the *Dinosauria*, are only known from the Trias. The genus *Dystrophæus*, referred provisionally to the *Sauropoda*, is likewise from deposits of that age. The typical genera, however, of all the orders and suborders are Jurassic forms, and on these especially the present classification is based. The *Hadrosauridæ* are the only family confined to the Cretaceous. Above this formation, there appears to be at present no satisfactory evidence of the existence of any *Dinosauria.*

* Quarterly Journal Geological Society of London. Vol. xxvi, p. 34. 1870.

MEAN ANNUAL RAINFALL.

THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

Art. VIII.—*The Flood of the Connecticut River Valley from the melting of the Quaternary Glacier*; by J. D. Dana.

The explanations offered in my last paper * with reference to the origin of the so-called "kames" in the Connecticut Valley, and of terrace-formations in general, suppose certain conditions and results that are fundamentally at variance with other views of Mr. Upham. It is necessary, therefore, to consider the facts bearing on these points of difference in order to clear the subject, if possible, of the doubts with which in some minds it is at present beset. These points involve the question as to the relations between the position, features and heights of the valley-deposits and the depth, pitch and velocity of the flooded river. The latter subjects are consequently among those that are discussed in the following pages. As the Connecticut was one of many flooded streams in Glacial America, the conclusions here deduced, if well established, have an importance as universal as the floods. This difference is however to be noted between New England rivers and many to the west or south of west, that the former were wholly within the glacier-covered region.

In the following pages I, first, briefly state what appears to have been the general condition of the Connecticut and its tributaries during the progress of the flood: and then consider: (2) the origin of the channel-way of the river; (3) the question as to which is the *normal upper* terrace in any part of the

* This Journal, xxii. 451, 1881.

valley, or that which most correctly registers the highest flood level; and next, take up the subject (4) of the dimensions, velocity and discharge of the flooded river, and (5) the bearing of the facts on the retreat of the glacier.

1. ***General conditions of the flooded rivers and tributaries during the melting of the glacier.***

1. *Like other river-floods.*—The view to which I have been led by the study of the phenomena of the Champlain period, or those of the melting glacier, is that a *river-flood then* was in most points like a river-flood now. The valleys were, at the outset, deep valleys, and generally of greater depth than at present; for many have thick deposits over the bottom that were left there by the flood.

The waters of the Connecticut, as well as of other streams, rose gradually; passed the ordinary modern limit of 20 to 30 feet; still kept on rising for a prolonged period, owing to the long continuation of the melting and the abundant rains of that eminently *pluvial* era; and, at last, they reached a height of 200 to 260 feet above modern low water in the river. During its progress and continuance, water, bearing sand and often gravel and stones, flowed down the slopes leading into the valley along all the smaller depressions of the surface as well as by the many tributary valleys. Abrasion, transportation and deposition, the ordinary agencies in river action, went forward, as usual, together; and so the waters kept a great channel open along the course of greatest velocity, like a modern river, and transported and deposited according to the supply and rate of movement.

Whenever, finally, the diminution in the supply of water from the melting glacier failed of compensation by an increase in the rains, the decline of the flood began; and, as the river retreated toward its present contracted condition, it dug down into the bottom deposits to make its new or modern water-channel and flood-grounds.

2. *Changes in tributaries with the progress of the flood.*—The waters rose concurrently in the main river and in its tributaries; all had augmented activity together. At first, little streams and large ones may have been alike great transporters of sand and gravel. But with increasing height of flood there would have been changes. Some of the fierce little torrents would soon have become quiet through submergence by the great river. Other longer ones, flowing in rapids from the remoter hills, would have had their embouchures set back, but notwithstanding would have continued their transportation of coarse gravel and finer material to the end, making most abundant and coarsest beds when the flood was at maximum

height and violence; and the deposits now at or about their mouths contain, at various levels, such evidences of their perpetual activity. Others larger still, that now flow in broadly expanded valleys, would have lost, through the flood, their former pitch and torrential character, and have become for the last few miles comparatively feeble in transportation, capable of carrying and depositing only the finer materials; although farther up stream they might have continued to work as before. White River was an example. Such a large stream might however have made coarse deposits at its mouth on the borders of the Connecticut, because of the concentration carried on by the drifting action of the current of the main river, and through contributions from ice-floes coming down the main river or its tributary.

3. *The till the chief source of transported materials.*—The tributary streams as well as the main river would have derived the chief part of their material for transport from the unstratified drift or till. For the glacier had already deposited it, or the larger part, and it lay over the wide surface of the country open to receive the flowing waters, and ready for easy removal by them.

The *western* tributaries, Wells River, White River and the rest, consequently, did not gather for transportation chiefly material from the Green Mountain rocks or those of other elevations about their sources, but the universal northern drift. Hence, the drift or till west of the river, while mainly from the northwest, came partly also—especially that over the western borders of the valley—from the region of the river and its head-affluents to the north and east of north; for the glacial scratches indicate movement of the ice of the valley in the general direction of the valley. Consequently, eastern and western tributaries and Connecticut river ice-floes may have carried in stones from the same northern and north-northeastern source.

Moreover, since the till consists ordinarily: of (1) stones, large and small, (2) earth or finely pulverized rock, and usually (3) of more or less clay, it supplied (*a*) clay for clay-beds, (*b*) sand for sand-beds, and (*c*) gravel and stones for coarser deposits. And, as the rising waters reached successively higher and higher till-covered levels, submerging ledges and the lower hills, and rising against the slopes of the higher, so clay-beds should have been formed from the clay of the till at various levels in the terrace formations, like the sand-beds and gravel beds;* but the extent of them should be relatively small, or in proportion roughly to the clay in the till. The material of clay-beds may have come also from other sources;

* The heights of many of the clay beds are mentioned beyond.

but there is a remarkable uniformity of characters in the clay beds, especially the higher, which seems to indicate that they had in general the same glacial source.

4. *Deposition. Terraces.*—As happens now, deposition should have taken place over the flood-grounds, either side of the channel, wherever the waters were more or less retarded, and over the bottom according as the velocity there allowed of it. Through these depositions, the terrace-formation and its terraces were made. Along the side of the swift-flowing stream, one or both, where coarse material was contributed by tributaries, the depositions may often have been of the coarsest kind, while 100 yards away they were of sand alone, as numerous examples illustrate.

With the increasing height of the waters, the flood-grounds would have received additions in height through new depositions. But this increase would have been *small, unless* the amount of material supplied for deposition were under constant augmentation so as to have kept pace with the increasing width of the stream, and most markedly so if for any long distance tributaries were absent or feeble carriers; and small, also, if the rise of the flood went on too rapidly to allow time for the slow work of transportation and deposition. The conditions for progress in the different parts of a valley would thus have been very diverse; and the diversity under them in the resulting height would have been greatly enhanced by variations as to breadth and depth, or receiving capacity, in the valley itself.

But meteorological phenomena have their long cycles; and these would have made the progress of the flood intermittent, causing times of slowly augmenting depth to alternate at long intervals with periods of nearly stationary level; and this circumstance might have afforded a chance for approximate uniformity of height in terrace-plains at certain levels. Such a long period of nearly stationary level might have given time for building up the deposits to a common height, that of the existing water level, under different rates of supply of material. over very wide regions. A greater height than the water-level is not generally produced in such cases because of the chiseling or abrading action carried on by the surface portion of the waters, and the fact that the surface is the upward limit of deposition.

In this way a terrace of nearly uniform height could have resulted; and, during another such intermission, another; and so on. Two prominent ranges of terrace-plains may be distinguished between the level of the modern flood-ground and that of maximum flood, one at 60 to 80 feet above modern low water and another 40 to 60 feet below the maximum.

According to the process described *the terrace-plains were*

formed during the rise of the waters. This, though contrary to the views ordinarily held, and to an early opinion of the writer, appears to be true for the larger part. Yet many variations in the levels were no doubt produced by the abrasions and depositions attending the decline of the flood.

An argument against the making of the terraces of the valley by abrasion, forced on my attention through all my examination of the Connecticut Valley the past season, is afforded by the character of those plains throughout the valley. Except in the vicinity of tributaries, the lower terrace-plains consist almost uniformly of fine sand or sandy loam or clay, like the deposits beneath. Had the plains resulted through the removal of overlying deposits, that is, the grading down of higher terraces to the level of the lower, the action of the abrading waters would have generally left behind much gravel over the surface. Nothing like this ordinarily exists over the lower terraces.

Such a gravelly surface is however oftentimes found over the upper terraces, or within 50 feet of the highest terrace-level, partly as a consequence of the increased velocity of the river when the flood was approaching its maximum height, but to some extent, also, as a result of abrasion, which has resulted in depressing the surface and occasionally in making what look like broad channel-ways over it. It is of importance to note that such abrasions over the terraces by the waters flowing above them are wholly different in kind from the channelling and gouging done subsequently after the flood had subsided.

5. *The era of the glacier over the Connecticut Valley and of its melting continuous.*—Along the southern glacier limit in North America west of New England, interglacial epochs subordinate to the general Glacial period have been recognized. In the Connecticut Valley region, however, I have found nothing to indicate any such variations in the ice. The southern end of the valley, on the Sound, was at least 30 miles north of the southern line of the glacier, and hence the region was wholly within that of thick ice; and this is probably the reason for the absence of such evidence. While the facts about the White Mountains prove the ice to have had a thickness of at least 5,000 feet, the position of the New Haven region on the Sound favors the idea of a thickness not less than 750 feet. The situation of the valley with reference to the glacier, and the hilly features of the adjoining country hence explain why the valley deposits should make a continuous series from the lowest to the highest.*

* The Champlain period is, as regards the glacier, a part of the Glacial period. But in view of the fact that a great physical change took place in the relations of the land and sea (as proved beyond), initiating the era of melting, it stands apart from the true Glacial period.

This last remark has no reference to the region of the White Mountains, where the ice may have been long continued, with the various phases of modern glacier-covered mountains, as urged by Professor C. H. Hitchcock in the first volume of the Report on the Geology of New Hampshire. Yet some of the transporting effects attributed by him to such local glaciers may, I think, be due to transportation by floating ice.

2. *A Channel-way a consequence of the flow in the flooded river.*

A channel-way exists as a consequence of the flow in all modern rivers. But, according to Mr. Upham, in his Geological Report on New Hampshire, the filling up of the Connecticut valley with stratified drift took place in the era of the melting, or the Champlain period, and the excavation of the channel and the making of the terraces, in a later era. He says, p. 15:

The material was "brought down by the glacial rivers from the melting ice sheet, or washed from the till after the ice had retreated;" and by this means "the open valleys became gradually filled with great depths of horizontally stratified gravel, sand and clay." "The modified drift thus increased in depth in the principal valleys through a long period, which may have continued until the last of the ice at the head of the valley and of its tributaries had disappeared." After this came the "Terrace Period," and during it, as the sentence following the last cited observes, "the rivers have been at work excavating deep and wide channels in this alluvium. The terraces mark heights at which, in this work of erosion, they have left portions of their successive flood plains." "In this way the Connecticut River, along the greater part of its course on the west border of New Hampshire, has excavated its ancient high flood plain of the Champlain period to a depth of from 150 to 200 feet for a width varying from one-eighth of a mile to one mile, leaving numerous terraces at each side."

On page 59, he says: "The formation of the terraces has taken place by excavation of a vast deposit that filled the valley level with these upper plains." On page 44: "When the river entered upon the work of excavating its present channel in the alluvium, the kame was a barrier which confined erosion to the area on one of its sides and protected its opposite side."

This hypothesis makes two great floods necessary to the results, one for transportation and deposition, and another for abrasion, when, in fact, one may have done both. In an ordinary river, the powers of transportation and abrasion are combined in their action; and a channel between flood-grounds exists because the transporting power is lessened on either side by loss of velocity. The channel and its alluvial borders thus take shape together—the former through the latter.

To make the depositions extend up to a common level across a valley, or to approximate to this condition, either (1) the valley must have no outlet and the water therefore no current or velocity, so that contributions from the bordering slopes shall deposit equally, as nearly as possible, over the general area; or (2) the amount of transported material must be so large that transportation and friction use up the working force of the stream and reduce its velocity almost to zero.

Neither of these conditions was a fact in the flooded Connecticut. This is manifest from the varying nature of the deposits; and from the oblique lamination and flow-and-plunge structure characterizing the bedding in many parts of the valley. It is equally evident from the fine straticulation of the sand-beds. Had the stream been so clogged by its transported material as nearly to lose its motion, the assorting and stratifying action of flowing water would not have been exhibited so universally, and especially not in producing so generally a fine straticulate bedding of the sands and clays, the little layers of the beds but a fraction of an inch thick. This structure, like the same in the alluvium of the Nile, is proof of deposition by flowing waters, for each little layer required a separate special act in the flowing movement, or else successive conditions of supply and deficiency such as come by the changes of the day, or season, or year. From one end of the valley to the other there is this evidence in favor of the Connecticut's having been, through all the flood, a free-flowing stream, very much as now.

We are therefore safe in concluding that in the Connecticut valley the great stream which deposited the sands and gravel flowed with considerable velocity; and, if so, the making of a channel would have gone forward with the making of the depositions, the current where of greatest velocity locating the channel, and retardation either side by friction along with the attendant conditions of eddies locating the depositions.

Further, as is illustrated in all modern streams, a channel-way should have steep sides. The present pitch of the terrace-fronts toward the river, 35° to 42°, corresponds to the angle of rest in sliding gravel or sand when dry or nearly so. However steep the fronts at their formation, the retreat of the waters at any time would have left them to this treatment of gravity, whether formed as the flood rose, or by abrasion along the riverward margin of the terraces while it was declining.

The channel-way being thus the result of the dynamics of flowing water, no ice was needed along it, or "kame" ridges on its sides, to fix its shape or limits.

The extensive terrace-formations of the Sacramento River valley, in California, among the first studied by the writer (a

little over forty years ago),* were deposits far away from the region of ice; for the glacier of the Sierra Nevada, according to Whitney, and also Brewer, did not reach down within 2,000 feet of their level. Yet they have nearly identical features with those of the Connecticut. This is true even to the greater coarseness, in many parts, of the upper deposits. The route of the party I was with, after reaching the valley of the Upper Sacramento, just south of latitude 40° 45′, led us for fifteen miles over a high terrace-plain covered thickly with stones one to three inches in diameter, much to the annoyance of our already jaded horses. The channel-way, or open space between the high terraces of the east and west sides of the river, the terrace-plains, the terrace-front of 40° and sometimes 90° through undermining abrasion, were peculiar only in their wonderful extent.

The *width* of the channel-way has other determining causes besides velocity: such as the amount of transported material for deposition, and the form of the enclosing valley, as already explained. Along the Hudson River below the Highlands, the waters at the time of the great flood were 75 to 95 feet above the present level; and yet, owing to the nearness of the rocky hills, the channel-way was not a fourth wider than the present river; for the higher terraces rise almost immediately from its banks. On the other hand, the channel-way of the Connecticut at Hartford, Conn., had a width of 12 miles; owing partly to the low level of the region, and largely to the long trap-range on the west, shutting out tributaries and their contributions of sand and gravel. The Farmington River which comes from that direction through a cut in the trap-range, and reaches the Connecticut half a dozen miles north of Hartford, left a large part of its transported material west of the range in the Farmington Valley, where it made terraces over a hundred feet in height.

3. *Normal upper terraces.*

Professor Edward Hitchcock, finding that the terraces of the Connecticut about the mouths of tributaries were much the highest, designated them, in his "Surface Geology," "delta-terraces:" and Mr. Upham, adopting the view, represents them as terraces above the level of the "highest normal terraces" of the valley. The difference in height between the two kinds of terraces, the "highest normal terraces," and the "delta-terraces," along some parts of the Connecticut, are stated by Mr. Upham to be 40 to 50 and sometimes 100 feet.

* October 11, 1841, on a land expedition from the Columbia River to San Francisco, connected with the U. S. Exploring Expedition under Captain Wilkes. See my Geological Report of the Expedition, 756 pp. 4to, 1849, pp. 659–674; and for an abstract, this Journal, II, vii, 257, 1849.

I cite here Mr. Upham's explanation of the delta-terraces and their relation to the "highest normal terraces," from page 16 of his Report. "Upon entering the large valleys, tributary streams of comparatively narrow channel and rapid descent frequently formed extensive deposits in the Champlain period, similar in material to the flood-plain of the main valley, but having a greater height. Sometimes these *deltas*, being partially undermined, form conspicuous terraces a hundred feet above the *highest normal terrace*, which is the remnant of the river's continuous flood-plain. The deposition of the modified drift of the main river was usually, not always, to the same level across the valley. The increased supply from tributaries was sometimes a temporary barrier, damming up the waters of the main valley above; and the current could then deposit its sediment principally upon one side, making the highest normal terrace quite different in elevation."

To understand this explanation, Mr. Upham's idea as to the filling of the valley with deposits before the making of the channel-way, considered on the preceding page, must be in mind. If the making of the channel-way and terraces went on together, as appears to have been the case, some other conclusion, both as to the "delta-terraces" and the "highest normal terraces," must be found. The terraces of the latter kind, in any part of the valley, are rightly the highest there observed by Mr. Upham, with the exception of the "delta-terraces;" but if the conditions in the drainage area of the Connecticut valley were those of a flooded river with simultaneously flooded tributaries, the so-called "delta terraces," or terraces at the mouths of tributaries, may mark the height of maximum flood in the main river. The ramifying streams would have constituted a continuous range of waters, like a river and its tributaries at the present time, and would have made a continuous system of deposits. The large tributary would have entered the Connecticut with no greater pitch perhaps than that of the Connecticut itself; while smaller streams might have had a somewhat higher pitch according to the slope of the surface beneath, or the amount of sand and gravel with which the waters were loaded; a pitch of *ten* feet a mile under the last-mentioned condition would be large, of *fifteen*, very large, and of *twenty* feet, improbable. Only in case a tributary had ridges about its mouth so as to favor the formation of a dam, or had had its way obstructed by a barrier of ice, would terraces of abnormal height and pitch have been made. Otherwise the waters of the Connecticut would have extended into the mouth of the tributary, the one blending with other. The terraces of the latter, the so-called "delta-terraces," might thus have been part of the terrace formations of the main river. And such "delta-ter-

races," especially those that project out into the Connecticut valley so as to terrace it for some distance, may be and generally are, the best indicators of maximum flood-level to be found, the true highest normal terraces; because, as already explained, the supply of detritus for terrace-making was there the greatest. Were the waters so clogged by the material under transportation as to flow like mud, the angle of pitch might be even as high as 15 or 20 degrees. But the stratified and straticulate structure of the deposits proves that such a condition was of rare occurrence.

From this obvious relation of the tributary terraces to those of the main river it became of the highest importance to ascertain whether the "delta-terraces" of the different tributaries might be safely taken or not as the highest normal Connecticut terraces for the part of the valley in which they occur, and the study of this point was one of the prominent objects before me in my examination of the Connecticut valley. I found, in nearly every case investigated, that the outer part of the tributary terraces would have been within the range of the flood waters of the Connecticut; so that, while the tributary was pouring in its abundant detritus, the main river would have been distributing and leveling it. This was so with Oliverian Brook in Haverhill, where it opened on the Connecticut. The normal terrace of the Connecticut, at the mouth of this stream, is stated by Upham to be only 83 feet above low water in the river, while this brook opens on the valley with a terrace over 200 feet in height. That this brook should have held its waters up to this great height and made a terrace at that level, when those of the Connecticut were more than 100 feet below, is not possible, unless the side of the Connecticut against the mouth of the stream were blocked with solid ice; and this condition is shown by other facts not to have existed. The facts are similar in the case of the "delta-terrace" of Israel's Brook in Lancaster; of Jacob's Brook in Orford, five miles north of Thetford; of Eastman's Brook in Piermont; and of most other delta-terraces.

The true *normal upper* terraces of a valley are *those that register the same high flood-level.* They are not always easy to be distinguished, because of the inequalities in height from unequal deposition or subsequent abrasion; but with careful comparisons good general results can be reached.

The range of *normal* upper terraces along a valley should have a pitch down stream corresponding in a general way with that which the river had at the time of the flood. Mr. Upham's Report states that the upper terrace of the Connecticut valley becomes *suddenly lower* above Thetford, where the long "kame" ends; is reduced at Ely, two miles above Thetford, from a

height above low water in the river of 140 feet to that of only 55 feet; that it has this low level, continued northward, with little change, for eighteen miles, or more than half way to the mouth of the Passumpsic; and that at Haverhill, seventeen miles north of Thetford, the "highest normal terrace" is 83 feet above the river, while twelve miles to the north it is 135 feet. But, taking the terraces at the mouths of tributaries as marking the flood-level along this part of the valley—the so-called "delta-terraces" of Oliverian Brook, Jacob's Brook, Eastman's Brook and others—and then the low terraces referred to become simply the lower terraces along a part of the valley in which the highest normal terraces are wanting, except at the mouths of tributaries.*

With regard to the high terrace-plain of Haverhill there are other facts besides those connected with the terraces of Oliverian Brook; and these are presented on a following page.

[To be continued.]

ART. IX.—*Geology of the Diamond;* by O. A. DERBY.

TWO papers on this subject have lately appeared in Brazil in the Portuguese language. One by Professor H. Gorceix, of which an abstract was given in the September number of this Journal, treats only incidentally of the diamond. Its conclusions are, that the diamond, like the topaz, originated in the series of granular quartzites (itacolumites) and unctuous schists, which is so largely developed in Minas Geraes, and that the itacolumite is possibly the original matrix of the gem.

In a paper by myself, published in vol. v of the Archivos do Museu Nacional of Rio de Janeiro, the famous locality of Grão Mogol, in which diamonds are found in quartzite, is discussed. It is shown that, under the name of itacolumite, two very distinct geological series have been confounded. The older series, including the true flaggy and often flexible quartzite to which the name should be limited, is intercalated with the unctuous (hydro-mica) schists and itabirites. The newer series is composed almost exclusively of quartzite, which in its finer parts is almost indistinguishable from true itacolumite, but which, in places, passes to a conglomerate containing pebbles of all the rocks of the older series. Throughout the diamond region of the Serra do Espinhaco this quartzite lies in well-marked unconformability on the upturned edges of the lower, though, since

* Mr. Upham explains, (p. 79.) the existence of terraces of small height as the "highest normal terraces," in some places low while high elsewhere, by assuming "an irregular rate of retreat of the ice-sheet, allowing long and abundant deposition in some portions, but much less in other portions of the valley."

the localities where the two quartzites can be seen in juxtaposition and where they are at the same time clearly distinguishable one from the other are few, this unconformability has escaped notice or has only been doubtfully recorded. The distinction between the two series of quartzite being established, it is shown that the diamond-bearing rock of Grão Mogol most probably belongs to the newer series, and that the diamond entered into its composition ready-formed like any other pebble. The locality of São João da Chapada, where the diamond has been mined in clay (*barro*), is described. It is shown that the mine is excavated in the undisturbed soft material resulting from the decomposition of beds of unctuous schists underlying a bed of quartzite (itacolumite) which appears at the entrance of the mine. The diamond-bearing material was not exposed *in situ*, but two masses dislocated by slides were pointed out by a negro, who knew the mine thoroughly, as the diamantiferous *barro*. One consisted of a black clayey mass which, on a fresh fracture, revealed thin alternating layers of white clay resembling lithomarge and black pulverescent iron oxide. The other mass consisted of a portion of a quartz vein, the quartz being much fractured and traversed by brilliant plates of specular iron, with a mass of decomposed shale adhering to one side, and with an undisturbed mass of red clay adhering to the other side, to which in turn was attached a mass of decomposed shale. The vein nature of this mass was unmistakable. The red clay, which was said to be the diamond-bearing material, is rich in iron, and on treatment with acids leaves white quartz sand and an abundant black sand, consisting for the most part of microscopic tourmalines, according to the determination of Professor J. W. Mallet. Small hexagonal crystals are also described by H. Rose in a mass of *barro* containing a diamond obtained at São João by Messrs. Heusser and Claraz. It was concluded from these observations that the diamond occurs at São João in its original matrix, and that this matrix is a vein of quartz accompanied by a rock of unknown nature, but containing iron and tourmalines traversing the series of unctuous schists and itacolumites.

Since the publication of these papers, both Professor Gorceix and myself have revisited the diamond region, and these views have been fully confirmed. A specimen of rock from Grão Mogol, obtained through the kindness of Dr. Cartão Jardim, shows distinctly by the side of a diamond a rounded water-worn pebble, and Professor Gorceix was so fortunate as to extract, under his own immediate supervision and with all necessary precautions, several diamonds from the *barro* of the São João mine.

Near Diamantina I examined a mine in a rotten conglomer-

ate, which I suppose to belong to the same series as that of Grão Mogol. At other points, near the São Francisco river, diamonds appear in a region of a newer (though probably Paleozoic) conglomerate, and in the province of Paraná, in a region of Devonian sandstone and conglomerate. In all these cases the diamond has most probably come out from its secondary deposit—the conglomerate. Of course all rocks newer than the original formation and formed from its debris *may* contain the diamond. The original formation is most probably of Cambrian age.

Art. X.—*On the Algebraic Expression of the Diurnal Variation of Temperature;* by B. A. Gould.*

Although the general principles, which I am about to consider, apply to the cyclical mean variations of all the meteorological elements, we will restrict ourselves at present to the question of the diurnal changes of temperature; not merely for greater brevity, and because these fluctuations have a wider range and are relatively less affected by abnormal influences than those of the atmospheric pressure, moisture, etc., but because they have been made the subject of more extensive investigation, and because it is more especially regarding these that serious and harmful misapprehensions appear to exist.

It can scarcely be questioned by any one, who will give the subject his unbiased reflection, that a phenomenon due to the rotation and revolution of the earth,—however its direct manifestations may be modified by indirect and collateral influences, also purely natural,—must be governed by general laws which cannot fail to become manifest in the mean of observations sufficiently numerous. For if the indirect perturbations of the fundamental law belong to the class which may properly be regarded as casual, they will be eliminated from the mean values; and if they are not of this class they must and should be included in the general law which it is desired to discover.

Nor can it be reasonably denied, that if the diurnal variation be in fact governed by a general law, this must be of a cyclical nature, and capable of expression by some formula which completes its period with the solar day.

There are various formulas of this class, many of them interconvertible by simple analytic modifications; but none, of a thoroughly general character, which is simpler than a series progressing according to sines and cosines of successive multiples of the time elapsed since an adopted epoch. For phenom-

* Translated from Vol. II, Chapter vi, of the "Anales de la Oficina Meteorologica Argentina," by the author.

ena of the class in question, where the curve is continuous, this is of absolute generality; and, although other forms of expression may claim equal accuracy, none surpasses, or probably equals, it in the ease with which its constants may be computed, or the facility with which its value may be deduced for any value of the variable. It is unlikely that these advantages would escape the attention of any mathematician who might desire to give algebraic expression to the law of a periodic phenomenon. But it is generally known among meteorologists by the name of Bessel's formula, not so much because it was first employed by that great astronomer in studying the diurnal oscillations of the barometer, as on account of the elaborate articles in which he long afterward pointed out its generality, its convergence, and the special circumstances which facilitate its employment and application; and earnestly commended its employment to meteorologists in determining the diurnal and annual variations of atmospheric phenomena, the influence of winds from different directions, etc.

In fact a general algebraic formula gives, as Bessel said, the result of observations expressed in the concisest form. To translate his words: "by deducing a formula which represents a phenomenon, we meet its theory half-way; thus the observed longitudes of the sun, if thus expressed as functions of the annual period would have given a formula from which, were Keppler's discovery yet unmade, the elliptic motion would be far more easily recognized than from the observations directly. .... The periodic phenomena of meteorology belong to the same class, and the determination of their formulas, by means of observation, enables us to subject them to the readiest and most complete examination; so that whatever is to be explained by theory may be more directly deduced from the formulas than from the observations themselves or from the curves by which it is customary to represent the results of unknown laws."

The only true object of scientific investigation is the determination of principles and laws; and it may well be questioned what high aim can be attained by accumulating special results without such generalization.

It is therefore with deep regret, as well as surprise, that we have seen the eminent director of the Physical Central Observatory of Russia, under whose immediate supervision stand all the physical observations officially made in that vast realm, express himself in terms like the following, which I quote from among very many other statements of the same sort:

"How much time has been uselessly squandered in observations laboriously carried on through day and night, and in extended and far more useless calculations of the same by the Lambert-Bessel interpolation formula."

"In the lately published volume of the physical observations by the American expedition of the Polaris, Mr. —— has performed the most disheartening task of utterly useless calculation of all the meteorological elements according to Bessel's formula. What a pity that the time was thus lost which might have been employed in making better use of these excellent observations!"

"If then, under the erroneous idea that a certain number of terms of the Lambert-Bessel interpolation-formula can give the law of the diurnal variation of temperature, it has in many cases been sought to deduce therefrom the values for intermediate hours, or for the maxima or minima, ... we cannot wonder at the failure of such calculations."

"The application of Bessel's formula to represent the daily course of the temperature has, thus far, much more hindered than advanced our knowledge of the same."

These citations are perhaps more than sufficient for my purposes; which are: first, to show the facility with which a backward step may be taken, even by one whose services to his department of science have been and are distinguished and undeniable, when a dominant idea is allowed to distort his judgment; and secondly, to oppose the influences of argument and demonstration to these attempts at discouraging what I believe to be the only mode by which meteorology can become a science, and by which it bids fair soon to attain that rank.

Had the author perceived that the sine-formula is not simply a means of interpolation but a concise mode of general, complete and definite expression of a cyclical law, he would have aimed his denunciations at its frequent misapplication, but not at its use. The immediate origin of his strongly expressed opinions seems to have been his recognition of a relatively sharp bend in the curve of mean temperature at many stations, near the time of sunrise, and of sundry discordances between the epochs of maxima and minima as deduced under his direction by graphical methods, on the one hand, and by computation on the other. But it would be strange if the upward bend near sunrise should not be essentially balanced by a downward flexure after sunset, although the effect of this might be less conspicuous in the curve when graphically delineated, and the sharpness with which the moments of maxima and minima may be determined depends upon the form of the curve in their vicinity. Inasmuch as the minimum usually precedes sunrise by only a small interval, while the maximum generally precedes sunset by a very considerable one, a want of symmetry in the shape of the curve near the two daily extremes ought to be expected. Using identical data, it is a remarkable assertion that the free hand and judgment of a draughtsman can afford a more correct representation of the true curve than would be

obtained from accurate numerical calculation by means of the formula.

I am not aware that it has ever been considered desirable to base extended numerical calculations upon observations made more frequently than once an hour, for the determination of the diurnal curve; nor do I understand that the employment of such an increased number is now advocated. Were this desired, the influence of the additional observations could, if perceptible, be introduced into the formula quite as well as into the graphical sketch. It may therefore be assumed that the form of the diurnal curve, as afforded by hourly observations is amply sufficient for all the present purposes of scientific inquiry.

So much being premised, it may be well briefly to consider, even though only in an elementary manner, how and to what extent the formula in question may find legitimate application.

Denoting by h the number of hours elapsed since any given moment (for which we will, as usual, adopt that of midnight), the observed temperature will be represented with absolute precision for each one of the twenty-four hours, by the formula which, in its most compact and elegant form, may be written

$$T_h = M + a\sin(h + A) + b\sin(2h + B) + c\sin(3h + C) + d\sin(4h + D) + \ldots\ldots l\sin(12h + L)$$

in which a, A, b, B, c, C, etc., are constants which can only be determined by observation, and M is the mean of the twenty-four equidistant observations, this being the "daily mean" as defined by the established usage of physicists. It is perhaps needless to add that h should in strictness be made to denote hours of true and not of mean time; but this is a point which need not be considered if the length of the interval, for which the formula is determined, be either such as to eliminate the equation of time from the means of the daily observations, or so short that its inclusion may be recognized and allowed for, if desired.

An absolute representation of each of the twenty-four hourly observations, although afforded by the formula if its full number of twelve terms be employed,* is more than the demands of meteorology require; for all the errors of observation, not eliminated from the data, would thereby be reproduced, whereas by

* The curious numerical values upon p. 60 of Dr. Wild's "*Temperatur-Verhältnisse des Russischen Reiches*" from which it is inferred that the legitimate results from twenty-four equidistant observations cannot be fully represented by a formula containing twenty-four constants, are vitiated by the joint effect of an error of computation and the employment of an insufficient number of decimals. The effect of these errors is quite insignificant, it is true, and amounts to only a very few hundredths of a degree; but it is precisely upon these small quantities, much inferior in magnitude to the unavoidable errors of observation, that the whole argument of the author depends.

the omission of the latest terms these errors will be equated out to any desired extent in the same way that this end could be attained by graphical methods, but with far more accuracy. And a general expression, which sufficiently represents the known mean temperature at intervals of an hour throughout the day, cannot fail to give that which corresponds to any intermediate moment with all the exactness needful in the present state of science. But since each variable term of the equation as above written contains two unknown quantities, its determination demands, in the absence of other data, a knowledge of the temperature corresponding to two different hours at proper intervals.

As regards the degree of minuteness with which it is desirable that the formula should represent the original observations, there is much to say: but it will suffice in this place to call attention to the fact that the mean of values derived from a lifetime of observations would probably be inadequate to represent the true typical value, even within the limits of appreciable error. Most of the so-called casual influences, which so greatly disturb the normal values that the result of a single year's observations affords but a first approximation to the fundamental law,—are it is true, themselves subject to the law of probabilities, and are eliminated from the mean of the observations made during a large number of successive years. But in general the number of years requisite for such elimination will be far greater than is available; so that any minute and scrupulous attention to the computation of quantities smaller than the probable error of the data is misapplied, and even absurd, unless such quantities are demonstrably constant for the various individual values whose mean is taken. To devote punctilious attention to hundreths of a thermometric degree in results derived from data which are uncertain by ten or twenty times that amount is to "strain out a gnat and swallow a camel." From this point of view, also, it may be maintained that the last terms of the formula might be advantageously omitted.

The problem, which most frequently presents itself in practice, is to determine with sufficient approximation and from a relatively small number of daily observations, the most characteristic points of the curve and the daily mean. This is easy in proportion to the rapidity of convergence of the formula; and the degree of this rapidity affords a criterion of the extent to which the true law is represented by the earlier terms. If, by a few terms of the formula, containing no more than six or eight constants instead of twenty-four, the whole series of hourly temperatures can be represented within the limits of their probable errors, no further demonstration is requisite to show that the true law of daily variation may thereby be represented to an equal degree.

The general relations between the curves of daily variation at different places happily provide a means of deducing very approximate values of the constants from a smaller number of daily observations than would otherwise be requisite. Were the true moment known for either the maximum, or the minimum, or the true value of the daily mean, any one of these would supply the place of an additional daily observation. And the simple self-evident fact that, in the absence of very abnormal topographical conditions, the diurnal curve has but one point of contrary flexure, affords yet additional facilities for attaining the desired end.

The most important term of the formula, for various reasons, is the constant M, the daily mean temperature, which may be deduced with very considerable approximation from a relatively small number of observations. Thus in the mean of two values, corresponding to moments separated by an interval of half the day, all terms containing uneven multiples of h are eliminated, so that

$$\tfrac{1}{2}(T_h + T_{h+12}) = M + b \sin(2h + B) + d \sin(4h + D) + f \sin(6h + F) + \text{etc.},$$

while from the half difference of the same values we obtain the total amount of the omitted terms,

$$\tfrac{1}{2}(T_h - T_{h+12}) = a(\sin h + A) + c \sin(3h + C) + e \sin(5h + E) + \text{etc.},$$

a value which the, frequently very rapid, convergence of the series often renders extremely useful.

Thus from the mean of three equidistant values, all terms are eliminated in which the coefficient of h is not divisible by 3; so that

$$\tfrac{1}{3}(T_h + T_{h+8} + T_{h+16}) = M + c \sin(3h + C) + f \sin(6h + F) + \text{etc.}$$

Similarly the mean of four observations, at intervals of six hours, gives us

$$\tfrac{1}{4}(T_h + T_{h+6} + T_{h+12} + T_{h+18}) = M + d \sin(4h + D) + \text{etc.},$$

in which the first variable term is generally of small importance, and the remaining two absolutely insignificant.

And, in general, all those terms which do not depend upon multiples of nh are eliminated from the mean of n equidistant values so that the mean of observations made at intervals of three hours will differ from the daily mean only by the amount of the eighth term of the general formula; and that deduced from two hourly observations will differ from it only by the twelfth term. How small the coefficients of these high terms really are, will soon be seen.

From considerations analogous to the foregoing, we may easily perceive what is the amount by which the mean of determinations, made at any given hours of the day, will differ from the true daily mean. For example, if there be three daily determinations at the hours $h+m$, $h+n$, $h+p$, their mean will be

$$\mathrm{M}+aq_1 \sin (h+\mathrm{A}+\mathrm{Q}_1)+bq_2 \sin (2h+\mathrm{B}+\mathrm{Q}_2)+cq_3 \sin (3h+\mathrm{C}+\mathrm{Q}_3) + \text{etc.}$$

in which

$$q_1 \sin \mathrm{Q}_1=\tfrac{1}{3}(\sin m+\sin n+\sin p)\,;\ q_2 \sin \mathrm{Q}_2=\tfrac{1}{3}(\sin 2m+\sin 2n+\sin 2p)$$

$$q_1 \cos \mathrm{Q}_1=\tfrac{1}{3}(\cos m+\cos n+\cos p)\,;\ q_2 \cos \mathrm{Q}_2=\tfrac{1}{3}(\cos 2m+\cos 2n+\cos 2p) \text{ etc.}$$

Supposing the hours of observation to be 7^h, 14^h, and 21^h, as we have arranged them for this country, the corresponding quantities become

$$\begin{array}{llll} q_1=0{\cdot}161, & q_4=0{\cdot}667\,; & \mathrm{Q}_1=14^h, & \mathrm{Q}_4=\ 8^h \\ q_2=0{\cdot}244, & q_5=0{\cdot}311\,; & \mathrm{Q}_2=16^h, & \mathrm{Q}_5=10^h \\ q_3=0{\cdot}805, & q_6=0{\cdot}333\,; & \mathrm{Q}_3=18^h, & \mathrm{Q}_6=12^h \text{ etc.} \end{array}$$

Were the hours of observation the somewhat more symmetrical, although in the present case less advantageous, ones 7^h, 13^h, and 21^h, we should have

$$\begin{array}{llll} q_1=0{\cdot}173, & q_4=0{\cdot}577\,; & \mathrm{Q}_1=12^h & \mathrm{Q}_4=\ 6^h \\ q_2=0{\cdot}333, & q_5=0{\cdot}644\,; & \mathrm{Q}_2=18^h & \mathrm{Q}_5=12^h \\ q_3=0{\cdot}745, & q_6=0{\cdot}333\,; & \mathrm{Q}_3=16^h{\cdot}77 & \mathrm{Q}_6=\ 6^h \end{array}$$

The smallness of the coefficients for the earlier variable terms shows how near is the approach to the desired value of M. In fact the approximate value thus obtained, is usually sufficient, when considered in connection with the general form of the diurnal curve (also approximately known), to afford valuable aid in attaining a knowledge of the principal terms of the formula, as will hereafter be seen.

Let us now consider the problem in the form in which it practically offers itself for those places in the Argentine Republic at which we have been able to secure three daily observations. From these it is desired to infer the mean daily curve with the greatest degree of approximation which they can be made to yield; availing ourselves of every circumstance which can help to bring us nearer to the truth, yet avoiding illusory results which although derived from the data may have no foundation in the true law.

There are but three points in all the national territory at which more than three daily observations have been made

during a sufficient period to permit the form of the daily curve of temperature to be deduced independently. These are Buenos Ayres, where there were but two additional hours of observation; Bahia Blanca, where the different hours, though comparatively numerous, were at different dates; and Cordoba, where the series of hourly observations comprises but a small number of years. And moreover, those hours, which it has been found necessary to adopt for the regular observations made for this office in the various parts of the Argentine territory, are not those which permit an exact determination of the daily mean, even so far as the accuracy of the determination is uninfluenced by the third variable term of the general formula.

But notwithstanding these adverse circumstances, there are favorable considerations of yet more importance. In the first place, the configuration of the country is such as to make it probable that throughout the vast extent of the pampa regions, at least, the general form of the daily curve is not dissimilar; secondly, we have, in the periodic sine-formula arranged according to multiples of the time, a series of terms, each of which is independent of the rest, and susceptible of separate investigation, being in fact so many epicycles; thirdly, the mean daily curve cannot have more than one point of contrary flexure unless the local topographical conditions be so exceedingly abnormal that the investigation of the daily curve would have no general scientific value; and in addition to all these, the curvature in the vicinity of the maxima and minima is so gentle that a very considerable error as to the moment of their occurrence is productive of but comparatively slight influence upon the form of the computed curve, or upon other values which are determined through their agency.

If we neglect the variable terms beyond the third, we shall have from the mean of observations made at any of our stations at 7 A. M., 2 P. M., and 9 P. M. during a given interval, the three equations

$$(1)\quad T_{7}=M+a\sin(7^{h}+A)+b\sin(14^{h}+B)+c\sin(21^{h}+C)$$
$$(2)\quad T_{14}=M+a\sin(14^{h}+A)+b\sin(4^{h}+B)+c\sin(18^{h}+C)$$
$$(3)\quad T_{21}=M+a\sin(21^{h}+A)+b\sin(18^{h}+B)+c\sin(15^{h}+C)$$

and if the epochs H_1, H_2, of maximum and minimum together with the corresponding temperatures m_1, m_2, were known, we should have the four additional equations

$$(4)\quad 0=a\cos(H_1+A)+2b\cos(2H_1+B)+3c\cos(3H_1+C)$$
$$(5)\quad 0=a\cos(H_2+A)+2b\cos(2H_2+B)+3c\cos(3H_2+C)$$
$$(6)\quad m_1-M=a\sin(H_1+A)+b\sin(2H_1+B)+c\sin(3H_1+C)$$
$$(7)\quad m_2-M=a\sin(H_2+A)+b\sin(2H_2+B)+c\sin(3H_2+C)$$

and by the seven independent equations thus available, the seven unknown quantities which they contain could be fully determined; so that the form of the daily curve would be absolutely known, excepting so far as it might be affected by epicyclical terms which complete their period in six hours or still shorter aliquot parts of a day.

Unfortunately the data relative to the extremes are only roughly, even when at all, known; yet the condition that there shall be but one* contrary flexure in the curve, together with the possibility of inferring a very approximate value for M, from the observed temperatures at 7^h, 14^h, and 21^h, provide the means of remedying these deficiencies to a considerable extent; while it may be justifiable to assume an analogy between the form of the curve sought, and that of those already determined for Bahia Blanca, Buenos Ayres, and Cordoba, to an extent to diminish still further the probable errors of the determinations. In this way very approximate values of the constants of the first three terms may frequently be obtained; and although no one would maintain that an absolute representation of the true daily curve could thus be secured, still we should certainly obtain a curve of which the deviation from the true one is very small, and which intersects it in six nearly equidistant points.

The first, and usually the most troublesome, process to be

* Notwithstanding indications of secondary maxima and minima have been found in observations made at sundry places, and mentioned by Kämtz and Karsten, while they have been especialy discussed by Hellmann, the reality of the phenomenon seems by no means proved. The most conspicuous case of their occurrence is at St. Petersburg, in the new series of observations organized by Dr. Wild with such care that he thinks the error of a single determination cannot exceed 0·1 (*Temperatur-Verhältnisse*, p. 29). In the mean of the six years' observations of this series, minima, other than those which he accepts as the true ones, occur at about $3\frac{1}{2}^h$ in November, $21\frac{3}{4}^h$ in December, and $0\frac{1}{2}^h$ in January. Although the amounts of the abnormal fluctuations are petty in themselves, they are far from being unimportant relatively. Indeed for the month of December, for which the maximum mean temperature, as given by the observations, is 7°·36 at $13^h\ 45^m$, and the minimum 8°·28 at $21^h\ 42^m$, Wild adopts as the true minimum, 8°·03 at $9^h\ 0^m$, or only thirty-three minutes earlier than the epoch which he himself gives for the mean temperature of the day.

We cannot but share his opinion that this abnormal fluctuation, by reason of which the observed temperature remains below its minimum for twelve or thirteen hours of the twenty-four, is to be "considered as a remainder from non-periodic perturbations," and likely to disappear from the mean of many years' observations. This is made probable by the fact that the twenty-two years of the old series show no indications of such a phenomenon.

The real existence of any secondary maxima and minima is flatly denied by Wild, and in this we believe him to be correct. But in accounting for their apparent occurrence, he says that it is either simply due to irregular perturbations not equated out, or *generated by calculations with Bessel's formula* (*Temp. Verhältn.*, p. 103). Had he said "erroneously interred from inadequate data," there might have been a show of reason in his statement. But it ought to be needless to mention that errors can only be produced by the use of this general formula in the same way in which they can be caused by the use of a book of logarithms; namely by its misapplication.

effected is the determination of a sufficiently accurate value of M, the daily mean. When we know the epochs of maximum and minimum or the corresponding temperatures within narrow limits this is easy, for having once attained moderately correct values for M, m_1, and m_2, tentative processes will soon guide us to congruous values of all three which will accord with the known general form of the daily curve. This can be completely accomplished by numerical methods only, as must be the case with every process of the sort which can claim to be exact; but as is also commonly the case it may be greatly facilitated by graphical methods.

For a first approximate value of M, the mean of the temperatures observed at 7^h, 14^h and 21^h will usually suffice, although it is always too high, its value being

$$\mathrm{M}+0{\cdot}16\,a\sin(\mathrm{A}+14^h)+0{\cdot}24\,b\sin(\mathrm{B}+16^h)+0{\cdot}80\,c\sin(\mathrm{C}+18^h)+0{\cdot}67\,d\sin(\mathrm{D}+8^h)$$

but when the constants of either the first or second variable term are approximately known, a much closer estimate may be made by taking in the former case $\frac{1}{4}(\mathrm{T}_7+2\mathrm{T}_{14}+\mathrm{T}_{21})$ which gives

$$\mathrm{M}+0{\cdot}37\,a\sin(\mathrm{A}+14^h)+0{\cdot}07\,b\sin(\mathrm{B}+4^h)+0{\cdot}85\,c\sin(\mathrm{C}+18^h)+0{\cdot}72\,d\sin(\mathrm{D}+8^h)$$

or in the latter case $\frac{1}{5}(2\mathrm{T}_7+\mathrm{T}_{14}+2\mathrm{T}_{21})$ which gives

$$\mathrm{M}+0{\cdot}01\,a\sin(\mathrm{A}+2^h)+0{\cdot}49\,b\sin(\mathrm{B}+16^h)+0{\cdot}77\,c\sin(\mathrm{C}+18^h)+0{\cdot}60\,d\sin(\mathrm{D}+8^h)$$

and substituting the numerical values of the known constants. In practice it is almost always possible to estimate the magnitude of the unknown constants with sufficient correctness to deduce a very close approximation to the true values.

But, in the absence of any knowledge of the constants, a very near approach to the true daily mean may be generally obtained for this country from the combination $\frac{1}{17}(6\mathrm{T}_7+5\mathrm{T}_{14}+6\mathrm{T}_{21})$; this being equal to

$$\mathrm{M}+0{\cdot}11\,a\sin(\mathrm{A}+14^h)+0{\cdot}32\,b\sin(\mathrm{B}+16^h)+0{\cdot}79\,c\sin(\mathrm{C}+18^h)+0{\cdot}65\,d\sin(\mathrm{D}+8^h)$$

and the relations between the constants of the different terms being in this region such that the several variable terms in this formula nearly cancel one another.

With the preliminary value of M, obtained by any of these devices, is to be combined the approximate time H, of the daily maximum. This epoch, as also that of the minimum, is so variable on account of the large effect exerted upon it by disturbances of the casual class, that a very long series of years

would be needful for determining it with any accuracy. It is furthermore so uncertain, and its determination so insecure, owing to the great extent to which the time of its apparent occurrence is influenced by the inevitable errors of observation, that it may well be questioned how far the minutiæ of calculation can advance our real knowledge regarding it, and whether much time has not been uselessly expended in attempts to fix with precision a moment which is in its nature unprecise. But, without entering upon these questions, it may be stated that a considerable error in the assumed epoch will give rise to a relatively small error in the final result. Where no special means of forming an estimate can be made useful, it may be well to begin with the supposition that the highest temperature occurs at 2 P. M. daily.

If we disregard the third variable term in the equation (1) to (4), we have now a means of determining, first, approximate values for the constants a, A, b, B; and from these a corresponding curve, which must necessarily intersect the true mean daily curve in the three points given by observation. But, unless the assumed values of both M and H have been very near the truth, this very circumstance will cause the general form of the computed curve to be markedly discordant from that of the true one, already approximately known; and very frequently it will be found that double curvatures will present themselves as the only geometrical mode of satisfying the condition that the areas above and below the medial line must be equal.

A second computation is now to be made with a slight change in the assumed value of M, which a little tact on the part of the computer will usually enable him to bring nearer to the truth; but should a third be found needful, it will be convenient to change the assumption by about the same amount as before, to permit an easy use of the rule of proportion. It will be found that the increase or diminution of the values of the resultant constants depends upon the value assumed for M; and a comparison of the corresponding curves will usually permit its true value to be fixed within extremely narrow limits.

Adopting for M the value thus derived from the first assumption regarding the time of daily maximum,—the question next arises, to what extent any other assumption would bring the form of the curve into nearer analogy with any known one at some station not too diverse either in its geographical or its topographical relations. This may be determined in a similar way by varying the assumptions until a satisfactory result is attained. Should the previous value of H be found to require any considerable modification, the determination of M may be revised, although any change in this would be due to the influence of terms of the second order.

It is manifest that the trustworthiness of this method must depend upon a convergence of the successive approximations toward one and only one value of each of the desired constants, M and H. This may be tested whenever desired by a similar process, employing an assumed epoch for the daily minimum; or, what amounts essentially to the same, by comparing the epoch resulting from the determinations already made with that which is made probable by other considerations. In the case that observations of the minimum temperature exist, these will afford a more delicate criterion than those of the maximum, since the epoch of minimum is during most of the year far more distant from our hour of morning observation, than is that of maximum from 2 P. M.

It has been already stated that the earlier stages of the computation can be greatly facilitated by graphical processes, but in this place we are only considering the regular numerical routine available under all circumstances.

I append three examples, to illustrate the mode of computation. These are selected from among those places for which hourly observations are on record, because, while they are markedly diverse in their geographical relations, they also belong to the class most difficult to determine, namely that for which we can derive no indication regarding the form of the diurnal curve from a knowledge of that which corresponds to any place in the vicinity or even similarly situated. Thus we have a severe test of the degree of approximation to the true law which is attainable by means of the daily observations at 7^h, 14^h and 21^h, without any other data whatsoever. The discordances, between the hourly temperature thus inferred and those derived from actual observation, represent the sum-total of the various errors due to inaccuracies in determining the constants, and to the disregard of all terms of the general formula beyond that which depends on twice the time. It has been already mentioned that in practice the determinations may be much facilitated by the use of graphical methods for the first approximations; but we will dispense with them in our examples, and likewise with the various indirect processes which may often be advantageously employed; and begin in each case by assuming the mean of the three daily observations for the first approximation to the true daily mean, and 14^h for the hour of maximum. For readily perceiving the general form of the curve, a rough drawing is of course always desirable.

1. First, let us take the observations made in the month of January during five successive years at the island of St. Helena, and published in degrees of Réaumur's scale by Dove in his second series. Here we have $T_7 = 13{\cdot}05$, $T_{14} = 16{\cdot}02$, $T_{21} = 13{\cdot}74$, the mean of which is 14·27.

Putting this mean for M and 14^h for H_1, the equations (1) to (4) give $a=1{\cdot}09$, $A=225°$, $b=0{\cdot}71$, $B=41°$. The resultant curve has a strongly marked secondary minimum at 21^h with its corresponding maximum at about 1^h, showing this value of M to be inadmissible.

A second supposition, $M=14\,21$, gives $a=1{\cdot}27$, $A=227°$, $b=0{\cdot}59$, $B=44°$ and this curve also exhibits a contrary flexure analogous to the former although less pronounced.

A third supposition, $M=14{\cdot}15$, gives $a=1{\cdot}46$, $A=229°$, $b=0{\cdot}47$, $B=48°$, and since in this curve there is no secondary maximum, the question arises as to the value of M between 14·21 and 14·15 for which this disappears. It will quickly be perceived on trial that this value is very near to 14·18 for which $a=1{\cdot}36$, $A=228°$, $b=0{\cdot}53$, $B=46°$.

Inspecting now the corresponding curve and comparing it with straight lines drawn to connect the point for 14^h with those for the other two observations, it becomes evident at a glance that the hour of maximum was assumed too early, and that a better assumption would have been $14^h\,30^m$. This latter gives the equation

$$T=14{\cdot}18+1{\cdot}385\sin(h+224°\,24')+0{\cdot}508\sin(2h+26°\,41')$$

There is in this curve no indication of any failure to fulfill all the conditions of our problem; and in the total absence of other data, the equation may be regarded as a sufficient representation of the diurnal curve. Some slightly more probable values for the constants might be obtained by new trials, which would fix better limits for M with $14^h\,30^m$ and better limits for H_1 with $M=14{\cdot}18$; inasmuch as each of these determinations is quite close enough to render quantities of the second order negligible. Nevertheless any such additional calculations would imply a minuteness scarcely appropriate to the character of the problem. But did we possess any one of the not unfrequently available additional data which are afforded by an approximate knowledge of the time or value of the daily maximum or minimum, we should thus be enabled to fix the constants with much greater precision; while a knowledge of all of them would permit us to deduce with considerable accuracy those of an additional term in the formula.

The hourly values of the temperature which correspond to the curve just deduced are given below, side by side with those actually observed. The grouping of the algebraic signs in the residuals, and the relative magnitude of these, show how large is that part of them due to the omission of the term depending upon $3h$.

Hour.	Temperature.		O—C.	Hour.	Temperature.		O—C.
	Observed.	Computed.			Observed.	Computed.	
1^h	13°·36	13°·41	−0°·05	13^h	15°·85	15°·79	+0°·06
2	13·28	13·36	−0·08	14	16·02	16·02	0·00
3	13·18	13·25	−0·07	15	15·97	16·01	−0·04
4	13·15	13·12	+0·03	16	15·90	15·80	+0·10
5	13·10	13·00	+0·10	17	15·69	15·42	+0·27
6	13·06	12·96	+0·10	18	15·13	14·94	+0·19
7	13·05	13·05	0·00	19	14·48	14·47	+0·01
8	13·26	13·30	−0·04	20	13·95	14·04	−0·09
9	13·68	13·72	−0·04	21	13·74	13·74	0·00
10	14·26	14·24	+0·02	22	13·61	13·56	+0·05
11	14·83	14·83	0·00	23	13·52	13·47	+0·05
12	15·35	15·38	−0·03	24	13·45	13·44	+0·01

So far as it can be deduced from the hourly observations, the true formula to the 2^d variable term inclusive (i. e. with four constants) is

$$T = 14°{\cdot}20 + 1°{\cdot}415 \sin (h + 223°\ 48') + 0°{\cdot}500 \sin (2h + 20°\ 50')$$

and the true daily maximum is at $14^h\ 38^m$.

2. Let us next consider the observations made at Hobart Town in Tasmania during the month of January in eight successive years, also published by Dove and expressed in degrees of Réaumur. Here $T_7 = 11°{\cdot}90$, $T_{14} = 17{\cdot}29$, $T_{21} = 12{\cdot}07$, the mean of these three temperatures being 13·75.

Beginning with this for the value of M we find the secondary maximum to be very pronounced; and assuming successive values, inferior to this, we find that the highest which gives, for $H_1 = 14^h$, a line without contrary flexure is 13°·45, and that none above 13°·40 fails to show decided indications of a secondary maximum between 0^h and 4^h. For M = 13°·40 we have $a = 3{\cdot}22$, A = 238°·46, $b = 0{\cdot}68$, B = 32°·56, which represent a curve with rounded and flowing outlines. Yet even this not only exhibits a very marked want of symmetry between the portions above and below the medial line, but also shows in other ways the need of further modification. For instance, its minimum occurs before $2\frac{1}{2}$ A. M., or more than three hours before sunrise, which is totally abnormal for the latitude 42°; and although the general form of the curve near the maximum,—which is fixed within comparatively narrow limits by the three fundamental observations,—is demonstrably one of rapid rise and fall, yet that portion of the computed curve which corresponds to the night hours is abnormally flat. These considerations agree in indicating that the true value of M is still smaller.

If we assume M = 13°·35 we have $a = 3{\cdot}37$, A = 239° 30′, $b = 0{\cdot}59$, B = 39° 12′ these representing a curve which manifests the same peculiarity of a too early minimum. But by vary-

ing the epoch of the maximum, it becomes evident that the assumption of an earlier maximum will remedy this defect,—and chiefly by increasing the importance and modifying the epoch of the second variable term. Thus putting $H_1 = 13^h\ 44^m$ we find

$a = 3{\cdot}369$, $A = 240°\ 42'$, $b = 0{\cdot}61$, $B = 53°\ 57'$ and the minimum at $3^h\ 36^m$;

while for $H_1 = 13^h\ 36^m$ we find

$a = 3{\cdot}368$, $A = 240°\ 56'$, $b = 0{\cdot}63$, $B = 54°\ 46'$ and the minimum at $3^h\ 56^m$.

Plotting these curves we select the latter as possessing the more probable form of the two; thus giving, together with an absolute representation of the three fundamental observations, a curve of which the general form is normal and the epoch of minimum not improbable. These two conditions cease to exist when the assumed values of M and H_1 are much changed, and they fulfill approximately the function of that additional observation which would permit the constants to be rigorously determined.

Referring now to the series of hourly observations, we find these to be as given below. At their side are the temperatures which correspond to our approximate formula; and a glance at the column O—C suffices to show how largely the residuals are due to the neglected term depending upon $3h$.

Hour.	Temperature.		O—C.	Hour.	Temperature.		O—C.
	Observed.	Computed.			Observed.	Computed.	
1h	10°·79	10°·41	+0°·38	13h	17°·20	17°·25	−0°·05
2	10·49	10·23	+0·26	14	17·29	17·29	0·00
3	10·29	10·18	+0·11	15	16·98	16·96	+0·02
4	10·18	10·27	−0·09	16	16·58	16·33	+0 25
5	10·05	10·68	−0·63	17	15·95	15·50	+0·45
6	10·76	11·12	−0·36	18	14·76	14·56	+0·20
7	11·90	11·90	0·00	19	13·51	13·64	−0·13
8	13·11	12·89	+0·22	20	12·56	12·79	−0·23
9	14·26	13·99	+0·27	21	12·07	12·07	0·00
10	15·30	15·10	+0·20	22	11·67	11·50	+0·17
11	16·13	16·09	+0·04	23	11·33	11·03	+0·30
11	16·89	16·84	+0·05	24	11·04	10·68	+0·36

The true formula as deduced from the hourly observations is

$$T = 13{\cdot}38 + 3{\cdot}536 \sin (h + 239°\ 33') + 0{\cdot}645 \sin (2h + 66°\ 1') + 0{\cdot}365 \sin (3h + 34°\ 31')$$

the corresponding maximum occurring at $13^h\ 31^m$, and the minimum at $3^h\ 26^m$. The mean error of the approximate formula is $+0°{\cdot}25$.

3. As a third and last example we will take the important series of observations made at Upsala in Sweden during the ten years 1869–1879, and consider the mean diurnal variation during the entire year.

Here the three observations are $T_7 = 3{\cdot}25$, $T_{14} = 7{\cdot}48$, $T_{21} = 4{\cdot}07$, in degrees of the centigrade scale. Using for M the mean of these three temperatures we have a secondary maximum in the curve; and decreasing the assumed daily mean until the tendency to abnormal flexure disappears, we furthermore perceive that the epoch of maximum is probably later than 14^h.

Supposing then this epoch to be $14^h\ 36^m$, we find for $M = 4{\cdot}70$, $a = 2.29$, $A = 228°$, $b = 0{\cdot}52$, $B = 20°$, with an evident tendency to a secondary maximum and a very flattened curve for the night-hours. Even for $M = 4{\cdot}65$ the same characteristics are recognizable. But for $M = 4{\cdot}60$, for which the curve appears satisfactory in all other respects, we find the improbable epoch $2^h\ 42^m$ for the minimum.

It is furthermore readily seen that either an increased value of M, or an earlier value of H, will give a later epoch of minimum. Thus we have for

$M = 4{\cdot}65$	$H_1 = 14^h\ 36^m$	$a = 2{\cdot}45$	$A = 228°\ 55'$	$b = 0{\cdot}43$	$B = 18°\ 17'$	$H_2 = 3^h\ 24^m$
4·60	14 36	2·60	229 43	0·33	17 1	2 42
4·60	14 24	2·60	230 41	0·32	31 28	3 15
4·60	14 12	2·58	231 34	0·33	45 19	3 24
4·58	14 24	2·66	230 56	0·28	32 40	3 20

Plotting these curves, it is clear that either of the last three will give satisfactory results, although the general form of the last but one seems the more probable.

Comparing the observed values with those deduced from this system of constants, we find

Hour.	Temperature.		O—C.	Hour.	Temperature.		O—C.
	Observed.	Computed.			Observed.	Computed.	
1^h	2°·55	2°·55	0°·00	13^h	7°·28	7°·29	−0°·01
2	2·30	2·36	−0·06	14	7·48	7·43	0·00
3	2·10	2·27	−0·17	15	7·45	7·41	+0·04
4	2·02	2·28	−0·26	16	7·20	7·08	+0·12
5	2·19	2·43	−0·24	17	6·78	6·59	+0·19
6	2·60	2·75	−0·15	18	6·15	5·97	+0·18
7	3·25	3·25	0·00	19	5·46	5·31	+0·15
8	4·01	3·90	+0·11	20	4·75	4·66	+0·09
9	4·84	4·65	+0·19	21	4·07	4·07	0·00
10	5·64	5·47	+0·17	22	3·54	3·57	−0·03
11	6·36	6·23	+0·13	23	3·13	3·15	−0·02
12	6·91	6·86	+0·05	24	2·82	2·82	0·00

The true value of M, as determined by the hourly observations, is 4·62, the maximum being at $14^h\ 10^m$ and the minimum

at $3^h\,22^m$. The mean discordance 0°−C. deduced from the table of comparison is ±0°·13 which would be reduced to ±0°·10 by adding a third term, 0°·10 sin $(3^h+45°)$.

These examples will show how by a rough use of tentative processes a tolerable approximation to the true form of the diurnal curve may be obtained from observations made three times daily. The labor, though often considerable, is by no means so great in actual practice as might be inferred from the detailed description. A very little experience and tact are sufficient to indicate to the computer those hypothetical values which will guide him most readily to the desired end, this being the recognition of those limits for the unknown quantities within which they are not contraindicated and the selection of a probable curve within these, generally narrow, limits.

I do not fear that any unbiased person will misapprehend the claims here made in behalf of this mode of inquiry. It is of course only approximate; but in regions where the climatic relations have previously been unknown, it is certainly of high importance to obtain, from such data as may be accessible, determinations which are demonstrably not far from the truth; even though they may be destitute of that exactness which can only be obtained from the mean of many daily observations through an extended series of years.

But so soon as we are in possession of knowledge of other fundamental data to be combined with the three daily observations,—when for example we may infer from analogy the probable form of the true daily curve, or know the epoch or the temperature for the maximum or minimum, within moderate limits,—we may not only infer with confidence the constants of the second term, but may often deduce very fair values for the third.

Under ordinary circumstances this is not difficult, and it may therefore be well to consider the present state of our knowledge regarding the epochs of daily maximum and minimum. We will endeavor to avoid misplaced refinements of calculation, since attempts at minuteness in determining these epochs are for the most part justified neither by the nature of the phenomenon nor by the character of the observations: but will take into consideration only the unmistakable fact of the case.

The fact that the epochs of the daily extremes are to a high degree vague and uncertain cannot escape the most inattentive observer. It is of course the duty of the meteorologist to fix their typical values and the limits of their normal variation with such degree of precision as the nature of the case permits; still all endeavors must prove vain which aim at determining them with the minuteness which belongs to the epoch either of a sharply defined or of a tolerably regular phenome-

non. Cases are by no means infrequent in which the highest temperature of the day occurs as early as 8 A. M., or as late as 8 P. M. Sudden changes of wind, or in the amount of cloudiness exert so great an influence that great care is often needful for obtaining values for the epochs which shall be even approximately near to the normal ones. And allusion has already been made to the very great length of the period which would be requisite for determining these values with any precision. Two successive periods of ten years each might easily give average times for the daily maximum, differing by many minutes, whether the interval considered be one of 5, 7, 10, or 30 days, or the entire year. The next following would, in its turn, generally differ from both the previous ones; indeed the duration of the observations needed for obtaining a value, which should be essentially unchangeable by their longer continuance, is such that it has certainly been obtained for few, if indeed for any, places on the earth's surface. This certainly does not absolve us from the duty of investigating and remedying the sources of constant errors which would not probably disappear from the mean of a larger number of observations; but none the less is it futile to attempt to fix the epochs within limits which nature has not prescribed. To these considerations is to be added the independent one that, in many places, the diurnal curve of temperature varies so slightly at certain seasons in the vicinity of its extremes that a point of maximum or minimum value has scarcely more than a theoretical existence; so that small, and often inevitable, errors of observation would suffice to change the epochs by an amount relatively very large.

If determinations of the average times of the epochs are to be made within narrow limits of error and in such a way as to be serviceable for scientific ends, they must either be separately investigated for clear weather and cloudy, high barometer and low, north wind and south, dry air and moist, hot days and cool ones,—or else, what is far less practicable, observations must be employed which extend over a period sufficiently long for the effects of all such varying conditions to be eliminated from their mean results. Moreover, exact values, even though attainable, would contribute comparatively little to the progress of discovery, unless accompanied by determinations of the extent of their normal variation, and of the amount to which they are modified by influences analogous to those just mentioned.

The distinguished physicist, to whose criticisms and strong denunciations of the employment of the general mathematical formula we have alluded, has repeatedly asserted that errors in the times of daily maximum and minimum are produced by the employment of Bessel's formula; and that this places the

minima too early. Indeed he attempts to demonstrate these supposed facts by numerical illustrations derived from observations made at Katharinenburg in April for 18 years, and at Tiflis in May for 10 years. The deserved influence of Dr. Wild in all that relates to meteorological investigation gives to his opinion and counsel an importance which calls for a careful disproof of his mistakes in this respect, lest the progress of research be seriously impeded by the proposed disregard of algebraic generalization.

That a general mathematical formula, which absolutely represents all the fundamental observations, must afford more correct results than can be obtained from the same observations in any other way, would seem too nearly a truism to require mention. If graphical determinations, based on the same data as the numerical ones, differ from these, they must be erroneous; yet it is asserted (Temp. Verhältn, p. 61) that even with 12 terms of the formula (24 constants) the epoch of minimum for Tiflis as deduced from hourly mean temperatures, is not correctly given. It may be admitted that Dr. Wild's tabular view might at the first glance suggest such interpretation; and, furthermore, conceded that the small numerical errors,* which have apparently given him the impression that the formula failed to represent the observations, do not essentially affect the gradual advance of the epoch of minimum, as the several terms of the formula are successively incorporated in the computation. In this particular case it would appear that nearly the whole twelve terms are requisite for giving the correct epoch of mean minimum; if so, we must of course accept the fact, and investigate the influences to which it is due. These we cannot but believe to be exceptional, and to arise either from local peculiarities or errors of observation, — aggravated perhaps by the employment of an inadequate number of years.

Well founded exceptions might be taken to the way in which these results have been obtained, since they are not deduced from the pure observations, but from data which have been modified by an empirical correction, for the purpose of eliminating the so-called influence of annual variation. The course pursued has been practically equivalent to dividing the difference of the normal mean temperature for the first and last days of the month by the number of intermediate hours: and then by means of the hourly difference, thus obtained, modifying twenty-three out of the twenty-four daily observations in order to refer them to the epoch of the remaining one by applying the supposed amount of annual variation during the interval. The various statistical tabulations of the daily, monthly,

* These, although insignificant in themselves, are in fact sufficient to change the corresponding epoch of maximum by thirteen minutes, or from $14^h\ 15^m$ to $14^h\ 28^m$.

and yearly results are thus made numerically accordant; but at a sacrifice of real accuracy. The corrections thus applied have the effect of belatening the minimum in the spring half of the year and anticipating it in autumn. For it cannot seriously be maintained that the influence of an increase or decrease of the sun's declination continues through the night-hours as through the day. This influence is necessarily intermittent; in dealing with annual variations, we cannot use hours as the independent variables; although here also the numerical changes are small, and although their influence disappears from the daily means and from determinations based upon them, yet whatever effect they may have goes to produce distortion and error in the resultant curve of diurnal variation. In this very case of May at Tiflis, the observations themselves give $4^h\ 47^m{\cdot}3$ for the mean epoch of minimum, instead of $4^h\ 50^m{\cdot}5$, which results after they have been modified by this reduction for annual variation, or of $5^h\ 0^m$ as deduced graphically by Dr. Wild. This modification has a still greater effect upon the time of mean maximum, for it changes this epoch from its true value $14^h\ 18^m{\cdot}8$ to $14^h\ 28^m$ or to $14^h\ 32^m$ if we accept the graphical result.

But, leaving this relatively unimportant question, the most striking fact to be noted in the example now considered is that the form of the diurnal curve, in the vicinity of its maximum, is such that, while the minimum temperature—$4°{\cdot}60$, as given by only three variable terms, corresponds to an epoch $4^h\ 17^m{\cdot}6$, yet the analogous value—$4°{\cdot}76$, deduced from the full series of twelve terms, and only $0°{\cdot}16$ lower, corresponds to the epoch $4^h\ 50^m{\cdot}5$, more than half an hour later. That obtained graphically and given as the correct one by Dr. Wild, is, as above mentioned, $5^h\ 0^m$.

The accomplished physicist, whose views we reluctantly oppose, maintains that his method gives the epoch with accuracy to within 2^m. With reference to this we will only remark that careful trials, plotting the observations with the utmost care upon the scale employed by Dr. Wild, show that the graphical method could give any value from $4^h\ 48^m$ to $5^h\ 12^m$ according to the taste or fancy of the draughtsman. Tracing the curve as it results from the formula, its true form may be recognized. If graphical processes are to be trusted in such cases, they must be based upon more frequent observations:—half-hourly, at least, in case the result is to represent the actual mean epoch within eight or ten minutes. How inordinately the resultant epoch would be affected by the, certainly not improbable, error of a few hundredths of a degree in the mean observed temperature, either for 4^h or for 5^h, is manifest. It may not be amiss to add that the mean discordance between the observed and

calculated temperatures, using only three variable terms of the formula, is less than the tenth of a degree. Using five variable terms, it is less than four hundredths of a degree.

In case the preceding month, April, had been selected for the illustration instead of this exceptional one of May, we should have found the time of minimum when obtained by the use of only six variable terms to be one minute *later* than if deduced from the complete series.

Or if the next following month, June, had been taken, the formula with only five variable terms would have given the epoch of minimum not only within a single minute of that resulting from the full series, but also *later* than any of those resulting from the successive incorporation of the four following terms.

When we examine the results obtained for Katharinenburg, the case is analogous, but even more favorable for illustrating the facts to which we call attention. Here the formula with but five variable terms represents the observations with such completeness that the mean discordance amounts to only $0^{\circ}.02$. With eight variable terms the discordance does not exceed one one-hundredth of a degree at any hour from 2 to 7 A. M.; and the same minute results for the epoch of minimum as when the complete formula is used. Indeed, with only six variable terms, the difference does not exceed five minutes. The value obtained graphically by Dr. Wild is five minutes later than that which results from the formula using the same data; and careful trials, employing the scale used by him, have convinced me that curves may be so drawn as to seem equally plausible, while their times of minima vary by some fifteen minutes. The experiment can easily be tried by any one for himself; and it will be found that the errors, inevitably committed in the plotting and reading off, are far less than those resulting from the sketching of the curve.

The extreme variability and uncertainty of these mean epochs of diurnal maxima and minima find an excellent illustration in the values corresponding to successive years in the admirable series of hourly observations made at Upsala under the direction of Dr. Hildebrandson. During the eight years 1869–1876, the mean epoch of daily minimum, as deduced from all the observations of the year, fluctuated between the limits $3^{h}\ 32^{m}$, and $4^{h}\ 12^{m}$, and that of maximum from $13^{h}\ 51^{m}$, to $14^{h}\ 42^{m}$. Dr. Wild himself ackowledges that the mean epoch of daily minimum as deduced from a whole year's observations was "tolerably constant," when it varied by 50^{m} during the years from 1857 to 1862. [Temp. Verh., p. 54].

It has already been stated that in the trials for obtaining the daily mean, the time of maximum may, in the absence of any

knowledge, be at first advantageously assumed as 2 P. M.; and also show how a rough approximate knowledge of the epochs may be made to contribute essentially to that of the formula.

To aid the attainment of this let us consider the facts at our disposal regarding the values of these epochs in general.

Very extensive materials are available for this purpose, but it is safer to restrict ourselves to a limited number of points for which the observations have been scrutinized, and the inferences deduced, with special care, than to base our researches upon a larger number of less trustworthy results. For these reasons the values adopted by Dr. Wild in the work already cited, have generally been preferred to others; and those for a number of places, such as Upsala, Berne, Leipzig, Greenwich, St. Helena, Lisbon, have been specially determined here. All depend upon hourly observations, with the single exception of Schwerin; but at Santiago de Chile, and Valparaiso, the observations were made during only a few days in each month, in different years. At Santiago the total number of days' of observation was 130, at Valparaiso, 60. To facilitate the examination of the results here given, and the deduction of analogous ones for other places, it may be convenient for those who are not astronomers, to have ready access to general tables of the equation of time, the sun's declination, and the times of sunrise and sunset in different latitudes. Those which follow* represent the mean values; and although not strictly accurate in every year, they may be used without hesitation for meteorological purposes. The equation of time as here given is to be applied to the mean time, to obtain the apparent; or with reversed sign to the apparent if the mean is desired.

The first of these tables gives the mean values for each decade during the year, corresponding to our arrangement, according to which all the days subsequent to the 20th of each month are made to form the third decade. The second table gives the apparent time of sunrise if the latitude be North, and of sunset if it be South, for the middle of each month.

Our data relative to the mean epochs of the diurnal extremes are deduced from the observations in each month separately during the period considered, and also from the annual means; the number of years of observation employed being mentioned in each case. The values are given in apparent time; those of the observed maxima being counted from apparent noon, and those of the minima being given by the number of minutes before sunrise, for which moment the arrival of the sun's center at the horizon is used, without any correction for refraction.

* The tables mentioned are given in the original article, but are necessarily omitted here.—EDS.

The data thus collected afford some opportunity for generalization; but this we reserve for some future occasion; simply calling attention to the relatively small extent of deviation of the average epoch of maximum from 2 P. M., and to the large amount by which the average times of minimum, as deduced from the whole number of observations, differ from the mean of those deduced for the several months. The general tendency of the interval, between the minima and true sunrise, to increase with the latitude is also readily perceptible. This is of course due to the sun's near approach to the horizon long before its actual arrival there.

Desiring a rough test both of the average epoch of maximum, as deduced from a short period of observation, and of its ordinary extent of variation, I wrote in April, 1880, to several of the gentlemen, at different places, to whom we are indebted for our meteorological observations, asking them to note the temperature half-hourly for a period of some hours which should include the epochs of maximum during ten or twelve successive days.

These observations referred to apparent time give the following results:

Place.	Approx.Lat.	Period.	Mean Epoch of Maximum.	Uncertainty of Determinat'n.	Variation.
Bahia Blanca	38° 45′	May 12–23	2h 13m P. M.	5½m	1h 27m – 2h 48m
Buenos Aires	34 16	Apr. 21–30	2 22	4½	1 2 – 2 56
S. Antonio de Areco	34 13	Apr. 21–30	2 19½	3	1 38 – 2 44
Cordoba	31 25	May 1–10	2 14	3½	1 27 – 3 51
		May 11–20	2 11	6	11 28 – 3 40
Villa Hernandarias	31 15	May 1–14	2 45½	3	1 40 – 3 28
Goya	29 9	May 1–10	1 55½	5	12 48 – 2 48
Salta	24 50	Apr. 23–30	2 38	4	1 14 – 2 57

The column entitled "Uncertainty of Determination," contains the sum of the various estimated possible errors in plotting the observations, drawing the curves, and reading of the results. The limits of probable, or possible, errors of the last two classes depend of course, principally, upon the form of the curve itself. The column entitled "Variation," contains the difference between the extreme values on different days during the continuance of the series.

It will be seen that these results confirm our previous inferences.

That the later terms of the formula should become more important in high latitudes during the winter season is a manifest consequence of the inequality of the two portions into which the minimum divides the interval between the normal epochs of maximum. When sunrise occurs so early as to render this

inequality comparatively slight, the first variable term, the period of which is twelve hours, acquires an overwhelming significance; and the residuals which it leaves are disposed of with comparative ease by the other terms of long period. But when the sun rises later the reverse must be the case. By means of the data above collected, provisional assumptions of the form of the diurnal curve may often be so made as to afford important assistance in deducing its true form, with great approximation, from a small number of observations.

On the other hand, no argument is needed to show how unjustifiable is that frequent misuse of the general formula by which the values deduced for certain terms from observations made during the day time or at inadequate intervals, are employed to represent the nocturnal portion of the curve. Indeed it is usually the most important terms which are thus least accurately determined. Bi-hourly observations will give the constants as far as the 6th term; hourly ones, will give them as far as the 12th; but these same arguments, which call for hourly observations for accurate determination of the epochs, apply with equal force to semi-hourly ones, for a more exact determination still. How far the game is worth the candle, is an entirely distinct question.

Summing up the several conclusions at which we have arrived we find as follows:

1. The formula, depending upon the sines and cosines of multiples of the time since an arbitrary epoch, is a very simple, —probably the simplest,—form of expressing the law, of a cyclical variation of this class. It is not a mere formula of interpolation; nor can it, when legitimately used, give rise to any systematic error whatsoever.

2. If in such variation there be a general law, this will be made manifest by the relative inappreciableness of the higher terms; and the chief function of these will be to equate out the errors of observation.

3. Although the results of hourly observations may be absolutely expressed by the formula with twenty-four constants, yet the values given by such a formula would probably be in general less correct than those resulting from the use of fewer terms, first, because it would imply an absence of law in the variation; secondly, because it would necessarily include all errors of observation to their full extent, instead of equating them out.

4. Three daily observations, tolerably well distributed, together with an approximate value of the epoch of maximum and the condition of only one point of contrary flexure in the curve, give a close approximation to the true formula for the daily variation, so far as this can be expressed without includ-

ing those terms which complete their period in less than eight hours.

5. An approximate knowledge of the epoch of the maximum or minimum temperature, will, for each of them, enable us to add an additional constant to the formula with a good degree of approach to the truth.

6. The mean epochs of maximum or minimum can seldom be determined with precision even by employing the highest refinements of observation and calculation known to science. Indeed it appears unlikely that they ever have been ascertained for any points of the earth's surface with less uncertainty than several minutes. It is moreover questionable whether there are any such epochs sufficiently marked to permit determinations without the introduction of various conditions; unless by the employment of observations extending over a series of years sufficiently long to eliminate all the variety of conditions. Even if this be possible it will not be within the attainment of the present generation or their near posterity.

Art. XI.—*Celestial Chemistry from the Time of Newton;* by T. Sterry Hunt, LL.D., F.R.S.*

The late W. Vernon Harcourt, in 1845,† called attention to the remarkable perception of great chemical truths which is apparent in the Queries appended to the third book of Newton's *Optics*, as well as in his Hypothesis touching Light and Color. With regard to the latter, Harcourt then remarked, "it has, I think, scarcely been quoted, except by Dr. Young, and its existence is but little known, even among the best-informed scientific men." The essay in question was read before the Royal Society, December 9th and 16th, 1675, but remained unpublished till 1757, when Birch, at that time secretary to the Society, printed it, not without verbal inaccuracies, in the third volume of his History of the Royal Society; a work intended to serve as supplement to the Philosophical Transactions up to that date. In 1846, at the suggestion of Harcourt, the Hypothesis of Newton was again printed in the L. E. and D. Philosophical Magazine (volume xxix), and it subsequently appeared in the Appendix to the first volume of Brewster's Memoirs of Sir Isaac Newton, in 1855.

The time has come for further inquiries into the science of Newton, and I shall endeavor to show that a careful examina-

* Read before the Cambridge (England) Philosophical Society, November 28, 1881, and reprinted from its Proceedings.

† L. E. and D. Philos. Magazine, III, xxviii. 106 and 478; also xxix. 185.

tion of the writings of our great Natural Philosopher, in the light of the scientific progress of the last generation, renders still more evident the wonderful prevision of him who already, two centuries since, had anticipated most of the recent speculations and conclusions regarding cosmic chemistry.

As an introduction to the inquiries before us, and in order to show the real significance of the speculations of Newton, it will be necessary to review, somewhat at length, the history of certain views enunciated almost simultaneously by the late Sir Benjamin Brodie, of Oxford, and the present writer, and subsequently developed and extended by the latter. In part I of his Calculus of Chemical Operations, read before the Royal Society, May 3, 1866, and published in the Philosophical Transactions for that year, Brodie was led to assume the existence of certain ideal elements. These, he said "though now revealed to us through the numerical properties of chemical equations only as *implicit and dependent existences*, we cannot but surmise may sometimes become, or may in the past have been, *isolated and independent existences*." Shortly after this publication, in the spring of 1867, I spent several days in Paris with the late Henri Sainte-Claire Deville, repeating with him some of his remarkable experiments in chemical dissociation, the theory of which we then discussed in its relations to Faye's solar hypothesis. From Paris, in the month of May, I went, as the guest of Brodie, for a few days to Oxford, where I read for the first time and discussed with him his essay on the Calculus of Chemical Operations, in which connection occurred the very natural suggestion that his ideal elements might perhaps be liberated in solar fires, and thus be made evident to the spectroscope. I was then about to give, by invitation, a lecture before the Royal Institution on The Chemistry of the Primeval Earth, which was delivered May 31, 1867. A stenographic report of the lecture, revised by the author, was published in the Chemical News of June 21, 1867, and in the Proceedings of the Royal Institution. Therein, I considered the chemistry of nebulæ, sun and stars in the combined light of spectroscopic analysis and Deville's researches on dissociation, and concluded with the generalization that the "breaking-up of compounds, or dissociation of elements, by intense heat is a principle of universal application, so that we may suppose that all the elements which make up the sun, or our planet, would, when so intensely heated as to be in the gaseous condition which all matter is capable of assuming, remain uncombined; that is to say, would exist together in the state of chemical elements; whose further dissociation in stellar or nebulous masses may even give us evidence of matter still more elemental than that revealed in the experiments of the laboratory, where we can

only conjecture the compound nature of many of the so-called elementary substances."

The importance of this conception, in view of subsequent discoveries in spectroscopy and in stellar chemistry, has been well set forth by Lockyer in his late lectures on Solar Physics,* where, however, the generalization is described as having been first made by Brodie in 1867. A similar but later enunciation of the same idea by Clerk-Maxwell is also cited by Lockyer. Brodie, in fact, on the 6th of June, one week after my own lecture, gave a lecture on Ideal Chemistry before the Chemical Society of London, published in the Chemical News of June 14th, in which, with regard to his ideal elements, in further extension of the suggestion already put forth by him in the extract above given from his paper of May 6, 1866, he says "we may conceive that in remote ages the temperature of matter was much higher than it is now, and that these other things [the ideal elements] existed in the state of perfect gases—separate existences—uncombined." He further suggested, from spectroscopic evidence, that it is probable that "we may one day, from this source have revealed to us independent evidence of the existence of these ideal elements in the sun and stars."

During the months of June and July, 1867, I was absent on the continent, and this lecture of Brodie's remained wholly unknown to me until its republication in 1880, in a separate form, by its author,† with a preface, in which he pointed out that he had therein suggested the probable liberation of his ideal elements in the sun, referring at the same time to his paper of 1866, from which we have already quoted the only expression bearing on the possible independence of these ideal elements somewhere in time or in space.

The above statements are necessary in order to explain why it is that I have made no reference to Sir Benjamin Brodie on the several occasions on which, in the interval between 1867 and the present time, I have reiterated and enforced my views on the great significance of the hypothesis of celestial dissociation as giving rise to forms of matter more elemental than any known to us in terrestrial chemistry. The conception, as at first enunciated in somewhat different forms alike by Brodie and myself, was one to which we were both naturally, one might say inevitably, led by different paths from our respective fields of speculation, and which each might accept as in the highest degree probable, and make, as it were, his own. I write, therefore, in no spirit of invidious rivalry with my honored and lamented friend, but simply to clear myself from the charge, which might otherwise be brought against me, of

* Nature, August 25, 1881, vol. xxiv, p. 396.

† Ideal Chemistry, a Lecture. Macmillan, 1880.

having on various occasions within the past fourteen years, put forth and enlarged upon this conception without mentioning Sir Benjamin Brodie, whose only publication on the subject, so far as I am aware, was his lecture of 1867, unknown to me until its reprint in 1880.

It was at the grave of Priestley, in 1874, that I for the second time considered the doctrine of celestial dissociation, commencing with an account of the hypothesis put forward by F. W. Clarke, of Cincinnati, in January, 1873,* to explain the growing complexity which is observed when we compare the spectra of the white, yellow and red stars; in which he saw evidence of a progressive evolution of chemical species, by a stoichiogenic process, from more elemental forms of matter. I then referred to the further development of this view by Lockyer in his communication to the French Academy of Sciences in November of the same year, wherein he connected the successive appearance in celestial bodies of chemical species of higher and higher vapor-densities with the speculations of Dumas and Pettenkofer as to the composite nature of the chemical elements.† I then quoted from my lecture of 1867 the language already cited, to the effect that dissociation by intense heat in stellar worlds might give us more elemental forms of matter than any known on earth, and further suggested that the green line in the spectrum of the solar corona, which had been supposed to indicate a hitherto unknown substance, may be due to a "more elemental form of matter, which, though not seen in the nebulæ, is liberated by the intense heat of the solar sphere, and may possibly correspond to the primary matter conjectured by Dumas, having an equivalent weight one-fourth that of hydrogen." The suggestion of Lavoisier, that "hydrogen, nitrogen, and oxygen, with heat and light, might be regarded as simpler forms of matter from which all others are derived," was also noticed in connection with the fact that the nebulæ, which we conceive to be condensing into suns and planets, have hitherto shown evidences only of the presence of the first two of these elements, which, as is well-known, make up a large part of the gaseous envelope of our planet, in the forms of air and aqueous vapor. With this, I connected the hypothesis that our atmosphere and ocean are but portions of the universal medium which, in an attenuated form, fills the interstellary spaces; and further suggested as "a legitimate and plausible speculation," that "these same nebulæ and their resulting worlds may be evolved by a process of chemical condensation from this universal atmosphere, to which they would sustain a relation some-

* Clarke. "Evolution and the Spectroscope," Popular Science Monthly, New York, vol. ii, p. 32.

† Lockyer, Comptes Rendus, November 3, 1873.

what analogous to that of clouds and rain to the aqueous vapor around us."*

These views were reiterated in the preface to a second edition of my Chemical and Geological Essays, in 1878, and again before the British Association for the Advancement of Science at Dublin,† and before the French Academy of Sciences in the same year.‡ They were still further developed in an essay on the Chemical and Geological Relations of the Atmosphere, published in this Journal for May, 1880, in which attention was called to the important contribution to the subject by Mr. Lockyer in his ingenious and beautiful spectroscopic studies, the results of which are embodied in his "Discussion of the Working Hypothesis that the so-called Elements are Compound Bodies," communicated to the Royal Society, December 12, 1878. It was then remarked that the already noticed "speculation of Lavoisier is really an anticipation of that view to which spectroscopic study has led the chemists of to-day;" while it was said that the hypothesis put forth by the writer in 1874, "which seeks for a source of the nebulous matter itself, is perhaps a legitimate extension of the nebular hypothesis."

To show the connection of the above views with the philosophy of Newton, it now becomes necessary to give some account of the conception of the universal distribution of matter throughout space, both as regards its dynamical relations and its chemical composition. Passing over the speculations of the Greek physiologists, we come to the controversies on this subject in the seventeenth century, and find, in apparent opposition to the plenum maintained by Descartes and his followers, the teaching of Newton that "the heavens are void of all sensible matter." This statement is, however, qualified elsewhere by his assertion, that "to make way for the regular and lasting movements of the planets and comets, it is necessary to empty the heavens of all matter, except perhaps some very thin vapors, steams and effluvia arising from the atmospheres of the earth, planets and comets, and from such an exceedingly rare etherial medium as we have elsewhere described," etc. (*Optics*, Book III, Query 28).

In order to understand fully the views of Newton on this subject, it is necessary to compare carefully his various utterances, including the Hypothesis, in 1675, the first edition of the *Principia*, in 1687, the second edition, in 1713, and the various editions of the *Optics*. This work appeared in 1704, the third book, with its appended queries, having, according to its author's preface, been "put together out of scattered papers"

* A Century's Progress in Theoretical Chemistry, being an address at Northumberland, Penn., July 31, 1874; Amer. Chemist, vol. v, pp. 46–61, and Pop. Science Monthly, vi, p. 420.

† Nature, Aug. 29, 1878, vol. xviii, p. 475.

‡ Comptes Rendus, Sept. 23, 1878, vol. xxxviii, p. 452.

subsequent to the publication of the first edition of the *Principia.* The Latin translation of the *Optics*, by Dr. Clarke, which was published in 1706, and the second English edition, in 1718, contain successive additions to these queries, which are indicated in the notes to Horsley's edition of the works of Newton, and are important in this connection. From a collation of all these, we learn how the conceptions of the Hypothesis took shape, were re-inforced, and in great part incorporated in the *Principia.*

In the Hypothesis, he imagines "an etherial medium much of the same constitution with air, but far rarer, subtler, and more elastic." "But it is not to be supposed that this medium is one uniform matter, but composed partly of the main phlegmatic body of ether, partly of other various etherial spirits, much after the manner that air is compounded of the phlegmatic body of air intermixed with various vapors and exhalations." Newton further suggests in his Hypothesis that this complex spirit or ether, which, by its elasticity, is extended throughout all space, is in continual movement and interchange. "For nature is a perpetual circulatory worker, generating fluids out of solids, and solids out of fluids, fixed things out of volatile, and volatile out of fixed, subtile out of gross, and gross out of subtile; some things to ascend and make the upper terrestrial juices, rivers, and the atmosphere, and by consequence others to descend for a requital to the former. And as the earth, so perhaps may the sun imbibe this spirit copiously, to conserve his shining, and keep the planets from receding farther from him; and they that will may also suppose that this spirit affords or carries with it thither the solary fuel and material principle of life, and that the vast etherial spaces between us and the stars are for a sufficient repository for this food of the sun and planets."

The language of this last sentence, in which his late biographer, Sir David Brewster, regards Newton as "amusing himself with the extravagance of his speculations," at which "we may be allowed to smile,"* was not apparently regarded as unreasonable by its author when, more than ten years later, he quoted it in the postscript of his letter to Halley, dated Cambridge, June 20, 1686. The views therein contained, with the single exception of the suggestion regarding gravitation, have not wanted advocates in our own time, and many of them were embodied in the *Principia*, which Newton was then engaged in writing.

But this was not all: Newton saw in the cosmic circulation and the mutual convertibility of rare and dense forms of matter a universal law, and rising to a still bolder conception, which

* Brewster's Memoirs of Newton, vol. i, pp. 121 and 404.

completes his Hypothesis of the Universe, adds: "Perhaps the whole frame of nature may be nothing but various contextures of some certain etherial spirits or vapors, condensed, as it were, by precipitation, much after the same manner that vapors are condensed into water, or exhalations into grosser substances, though not so easily condensible; and after condensation wrought into various forms, at first by the immediate hand of the Creator, and ever since, by the power of nature, which, by virtue of the command 'increase and multiply,' became a complete imitator of the copy set her by the great Protoplast. Thus, perhaps may all things be originated from ether."

If now we look to the third book of the *Principia*, we shall find in proposition 41 the remarkable chemical argument by which Newton was led to regard the interstellary ether as affording "the material principle of life" and "the food of planets." Considering the exhalations from the tails of comets, he supposes that the vapors thus derived, being rarified, dilated, and spread through the whole heavens, are by gravity brought within the atmospheres of the planets, where they serve for the support of vegetable life. Inasmuch, moreover, as all vegetation is supported by fluids, and subsequently, by decay is, in part, changed into solids, by which the mass of the earth is augmented, he concludes that if these essential matters were not supplied from some external source, they must continually decrease, and at last fail. This vital and subtile part of our atmosphere, so important, though small in amount, he then supposed might come from the tails of comets.*

This appeared in the first edition of the *Principia*, in 1687. It was not until later that the conception of exhalations from other celestial bodies took shape in the mind of Newton, as we may learn from the *Optics*. Thus, in the first edition of this work, in Query 11, the sun and fixed stars are spoken of as

*"Vapor enim in spatiis illis liberrimis perpetuò rarescit, ac dilatatur. Quâ ratione fit ut cauda omnis ad extremitatem superiorem latior sit quàm juxta capita cometae. Eâ autem rarefactione vaporem perpetuò dilatatum diffundi tandem et spargi par coelos universos, deinde paulatim in planetas per gravitatem suam attrahi et cum eorum atmosphaeris miscerì, rationi consentaneum videtur. Nam quemadmodum maria ad constitutionem Terrae hujus omnino requirmntur, idque ut ex iis per calorem Solis vapores copiosè satis excitentur, qui vel in nubes coacti decidant in pluviis, et Terram omnem ad procreationem vegetabilium irrigent et nutriant; vel in frigidis montium verticibus condensati (ut aliqui cum ratione philosophantur) decurrant in fontes et flumina: sic ad conservationem marium et humorum in planetis requiri videntur cometae, ex quorum exhalationibus et vaporibus condensatis, quicquid liquoris per vegetationem et putrefactionem consumitur et in Terram aridam convertitur, continuò suppleri et reflci possit. Nam vegetabilia omnia ex liquoribus omninò crescunt, dein magnâ ex parte in Terram aridam per putrefactionem abeunt, et limus ex liquoribus putrefactis perpetuò decidit. Hinc moles Terrae aridae indies augetur, et liquores, nisi aliunde augmentum sumerent, perpetuò decresere deberent, ac tandem deficere. Porro suspicor spiritum illum, qui aëris nostri pars minima est, sed subtillissima et optima, et ad rerum omnium vitam requiritur, ex cometis praecipue venire."—*Newton, Principia*, lib. III, prop. XLI.

great earths, intensely heated, and surrounded with dense atmospheres which, by their weight, condense the exhalations arising from these hot bodies. To this Query is added, in 1706, the suggestion that the weight of such an atmosphere "may hinder the globe of the sun from being diminished except by the emission of light;" while in the second English edition, in 1718, we find a further addition, in the words "and a very small quantity of vapors and exhalations." A similar change of view appears in the Query now numbered 28, wherein we read of "places [almost] destitute of matter," and also that "the sun and planets gravitate towards each other without [dense] matter between." In these quotations, the two words in brackets are wanting in the edition of 1706, and first appear in that of 1718; while the language which we have in a previous page quoted from this same Query is found in the edition of 1706.

The Queries now numbered 17–24, appeared for the first time in the edition of 1718, and herein we find, in 18, the etherial medium spoken of as being "by its elastic force expanded through all the heavens." Of this medium, "which fills all space adequately," he asks, "may not its resistance be so small as to be inconsiderable," and scarcely to make any sensible alteration in the movements of the planets?* This complex ether of the interstellary space was thus, in the opinion of Newton, made up in part of matter common to the planetary and stellar atmospheres, the origin and importance of which is concisely stated in the paragraph which appears for the first time in 1713, in the second edition of the *Principia*, in the third book, at the end of proposition 42, here much augmented. In this statement, which serves to supplement and complete that already made in 1687, in proposition 41, we read, that the vapors which arise alike from the sun, the fixed stars and the tails of comets, may by gravity fall into the atmospheres of the planets, and there be condensed, and pass into the form of salts. sulphurs, (*id est*, combustible matters,) tinctures, clay, sand, coral and other terrestrial substances.†

The conception of Newton, who, while rejecting alike the plenum of the Cartesians, with its vortices, and an absolute vacuum, imagined space to be filled with an exceedingly attenuated matter, through which a free circulation of gaseous substances might take place between distant worlds, has found

* Compare this with Prop. x. Book III of the Principia.

† "Vapores autem, qui ex Sole et stellis fixis et caudis cometarum oriuntur, incidere possunt per gravitatem suam in atmosphaeras planetarum, et ibi condensari et converti in aquam et spiritos humidos, et subinde per lentem calorem in sales, et sulphura, et tincturas, et limum, et lutem, et argillam, et arenam, et lapides, et coralla, et substantias alias terrestres paulatim migrare."—*Newton*, *Principia*, lib. III, prop. XLII.

favor among modern thinkers, who seem to have been ignorant of his views. Sir William Grove in 1842, suggested that the medium of light and heat may be "a universally diffused matter," and subsequently, in 1843, in the chapter on Light, in his *Essay on the Correlation of Physical Forces*, concluded with regard to the atmospheres of the sun and the planets, that there is no reason "why these atmospheres should not be, with reference to each other, in a state of equilibrium. Ether, which term we may apply to the highly attenuated matter existing in the interplanetary spaces, being an expansion of some or all of these atmospheres, or of the more volatile portions of them, would thus furnish matter for the transmission of the modes of motion which we call light, heat, etc.; and possibly minute portions of the atmospheres may, by gradual accretions and subtractions, pass from planet to planet, forming a link of material communication between the distant monads of the universe." Subsequently, in his address as President of the British Association for the Advancement of Science, in 1866, Grove further suggested that this diffused matter may become a source of solar heat, "inasmuch as the sun may condense gaseous matter as it travels in space, and so heat may be produced."

Humboldt, also, in his *Cosmos*, considers the existence of a resisting medium in space, and says "of this impeding etherial and cosmical matter," it may be supposed that it is in motion, that it gravitates, notwithstanding its great tenuity, that it is condensed in the vicinity of the great mass of the sun, and that it may include exhalations from comets; in which connection he quotes from the 42nd proposition of the third book of the *Principia*. He further speaks comprehensively of "the vaporous matter of the incommensurable regions of space, whether, scattered without definite limits, it exists as a cosmical ether, or is condensed in nebulous masses and becomes comprised among the agglomerated bodies of the universe."* Humboldt also cites in this connection a suggestion made by Arago in the *Annuaire du Bureau des Longitudes* for 1842, as to the possibility of determining, by a comparison of its refractive power with that of terrestrial gases, the density of "the extremely rare matter occupying the regions of space."†

In 1854, Sir William Thomson published his note on the Possible Density of the Luminiferous Ether,‡ wherein he remarks "that there must be a medium of material communication throughout space to the remotest visible body, is a fundamental conception of the undulatory theory of light. Whether

* Cosmos, Otté's translation, Harper's ed., vol. i, pp. 82, 86.

† Ibid., vol. iii, p. 40.

‡ Trans. Roy. Soc. Edinburgh, vol. xxi, part 1; and Phil. Mag., 1855, vol. ix, p. 36.

or no this medium is (as appears to me most probable) a continuation of our own atmosphere, its existence cannot be questioned." He then attempts to fix an inferior limit to the density of the luminiferous medium in interplanetary space by considering the mechanical value of sunlight, as deduced from the value of solar radiation and the mechanical equivalent of the thermal unit. He concludes "that the luminiferous medium is enormously denser than the continuation of the terrestrial atmosphere would be in interplantary space if rarified according to Boyle's law always, and if the earth were at rest in a state of constant temperature, with an atmosphere of the actual density at its surface." The earth itself in moving through space "cannot displace less than 250 pounds of matter."

In 1870, W. Mattieu Williams published his very ingenious work entitled The Fuel of the Sun, in which, apparently without any knowledge of what had been written before with regard to an interstellary medium, he attempts to find therein the source of solar heat—the "solary fuel" of Newton. To quote his own language, "the gaseous ocean in which we are immersed is but a portion of the infinite atmosphere that fills the whole solidity of space, that links together all the elements of the universe, and diffuses among them light and heat, and all the other physical and vital forces which heat and light are capable of generating" (loc. cit. p. 5).

Since the days of Newton, however, no one had hitherto considered the interstellary matter from a chemical point of view. In 1874, as already shown, the writer had, in extension of the conception of Humboldt that its condensation gives rise to nebulæ, ventured the suggestion that from an etherial medium having the same composition as our own atmosphere, the chemical elements of the sun and the planets have been evolved, in accordance with the views of Brodie, Clarke, and Lockyer, by a stoichiogenic process; so that in the language of Newton's Hypothesis, "all things may be originated from ether."

It was not, however, until 1878, that, from a consideration of the chemical processes which have gone on at the earth's surface within recorded geological time, I was led to another step in this inquiry. That all the de-oxidized carbon found in the earth's crust in the forms of coal and graphite, as well as that existing in a diffused state, as bituminous or carbonaceous matter, has come, through vegetation, from atmospheric carbonic acid, appears certain. To the same source we must ascribe the carbonic acid of all the limestones which, since the dawn of life on our earth, have been deposited from its waters. It is through the sub-aërial decay of crystalline silicated rocks, and the direct formation of carbonate of lime, or of carbonates of magnesia and alkalies which have reacted on the calcium-salts of the pri-

meval ocean, that all limestones and dolomites have been generated. These, apart from the coaly matter, hold, locked up and withdrawn from the aërial circulation, an amount of carbonic acid which may be probably estimated at not less than 200 atmospheres equal in weight to our own. That this amount, or even a thousandth part of it, could have existed at any one time in our terrestrial atmosphere since the beginning of life on our planet is inconceivable, and that it could be supplied from the earth's interior is an hypothesis equally untenable.

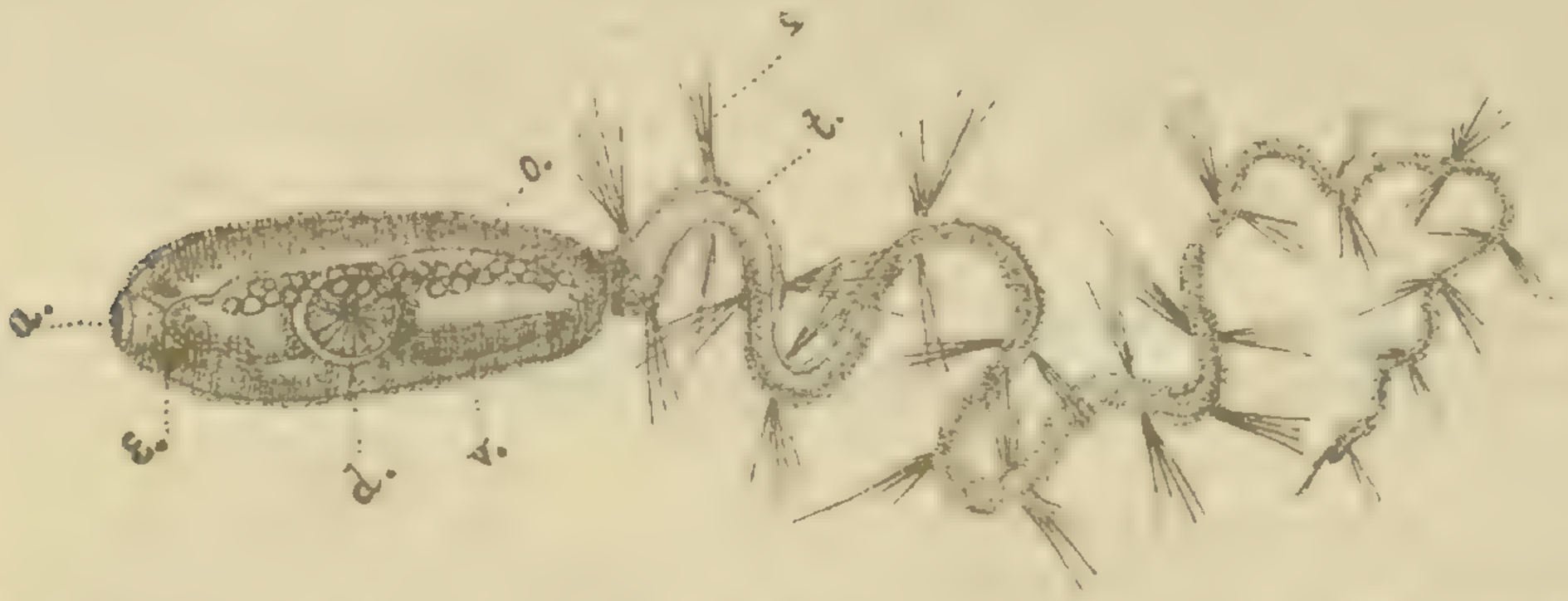
I was therefore led to admit for it an extra-terrestrial source, and to maintain that the carbonic acid has thence gradually come into our atmosphere to supply the deficiencies created by chemical processes at the earth's surface. Since similar processes are even now removing from our atmosphere this indispensable element, and fixing it in solid forms, it follows that except volcanic agency, which can only restore a portion of what was primarily derived from the atmosphere, there are on earth, besides organic decay, only the artificial processes of human industry which can furnish carbonic acid; so that but for a supply of this gas from the interstellary spaces now, as in the past, vegetation, and consequently animal life itself, would fail and perish from the earth, for want of this "food of planets."

Such were the conclusions, based on an induction from the facts of modern chemistry and geology, which I enunciated in my papers in 1878 and 1880, already quoted in the first part of this essay. I was at that time unacquainted with the Hypothesis of Newton, and with his remarkable reasoning contained in the 41st proposition of the third book of the *Principia*, in which he, so far as was possible with the chemical knowledge of his time, anticipated my own argument, and showed how and in what manner the interstellary ether may really afford the "food of planets," and, in a sense, "the material principle of life."

I have thus endeavored to bring before the Philosophical Society of Cambridge, a brief history of the development of this conception of an interstellary medium, and to show that the thought of two centuries has done little more than confirm the almost forgotten views of Newton. It is with feelings of peculiar gratification that I have been able to indite these pages within the very walls of the college in which our great philosopher lived and labored, and where, combining all the science of his time with a foresight which seems well-nigh divine, he was enabled, in the words of the poet, "to think again the great thought of the creation."

Art. XII.—*A Cercaria with Caudal Setæ;* by J. Walter Fewkes.

The interesting larva of a Trematode worm, described below, was found during my work last summer in the private laboratory of Mr. Alex. Agassiz at Newport, R. I. While watching the water in a glass jar, for the purpose of detecting new forms of pelagic life, my attention was attracted by the strange motions of a larva swimming near the surface. At first sight the unknown animal was mistaken for the nauplius of one of our common Cirripeds, which it closely resembles in the character of its movements. A microscopic examination, however, shows that it is a Cercaria, or larval Trematode, although it differs from any of these animals yet described. As nothing similar to it is to be found in the published figures of larval Trematodes, a figure and description is given below. The especially interesting feature of this Cercaria, and one which seems to me to justify this isolated publication of a description, is found in the annelid character of the tail. The larva, from this characteristic, may indicate some relationship which has not yet been pointed out, between the worms known as the Trematoda and the Annelida.



This Cercaria is marine in habitat, and is always found at or near the surface of the water. The length, when the body and tail are extended, is about one-sixteenth of an inch. Its motion through the water is never direct but, so far as was observed, consists of a "jerky" motion, brought about by the powerful strokes of its very muscular tail. This motion resembles very closely that of the nauplius of Balanus. The larva is just visible to the unaided eye and its body walls are very transparent. Under the microscope, with moderate magnifying powers, the contortions and motions of the tail are so rapid that they cannot be followed by the eye. As in all Cercariæ, the two marked divisions of the larva are the head and the tail.

The head or body is in no respect characteristic. Its shape is very variable, being sometimes contracted into a spherical

ball and at other times extended as represented in the figure. At the extremity of the head there is a mouth (*a*), which is sometimes seen to open and close. It is a circular orifice in which no proboscis could be seen. The stomach occupies a large part of the anterior central part of the body, and from it there is continued backward, a pair of blindly ending vessels, as in other Cercariæ. One of these cæca is shown in the figure (*v*). Many spherical oil globules (*o*), arranged in a row following the course of the cavity of the body, conceal the second.

A pair of black pigment patches (*e*) is found near the anterior extremity of the body. The most prominent structure of the body of the worm is a large medially placed sucker (*d*), which is situated superficially to the posterior end of the stomach near its bifurcation into the two vessels (*v*).

The tail is the most peculiar structure of this larval Trematode. Its general shape is hardly characteristic, and it owes its important interest to the appendages (*s*), found along its entire length. It is very muscular and extremely active.

The appendages (*s*) distinguish this larva from all other Cercariæ. At intervals along the whole length of the tail we find bundles of setæ arranged on opposite sides. These setæ, of which there are many in each bundle, are straight, inflexible and moved by muscles in the walls of the tail. Their resemblance to the setæ found in the segments of annelids is very great.

Ten specimens of this Cercaria were captured. It was impossible to raise them and all the specimens died soon after capture.

ART. XIII.—*Notice of the remarkable Marine Fauna occupying the outer banks off the Southern coast of New England, No.* 3; by A. E. VERRILL. (Brief Contributions to Zoology from the Museum of Yale College: No. XLIX.)

AFTER the printing of my last article, in the October number of this Journal, an additional trip to the outer grounds, off Martha's Vineyard, was made by the Fish Hawk, Sept. 21. Owing to unfavorable weather, only two successful hauls (1038, 1039) were made, but some very interesting species were procured. One of the most notable additions to the fauna was a large and perfect sea-urchin, with large spines nearly four inches long (*Dorocidaris papillata*). This had not been taken before on this coast, although not uncommon off the coasts of Europe, and beneath the Gulf Stream, off Florida, etc. The specimen taken at station 1038 measured $7\frac{1}{2}$ inches across the spines. A small comatula (*Antedon Sarsii*) was found at station 1038,

in 146 fathoms, in the greatest profusion, over 10,000 specimens coming up at a single haul. As usual, nearly all the specimens had dismembered themselves before reaching the surface. The great abundance of this and other recent crinoids at certain localities is parallel with the abundance of many ancient fossil crinoids, in particular regions.

In fact, a large number of species, belonging to various zoological groups, in this region are found living gregariously, in vast numbers, at particular spots, while they may not occur at all, or only sparingly, at other stations, in similar depths, and apparently identical in temperature and character of the bottom. Thus, among Echinoderms, the large ophiuran, *Ophioglypha Sarsii*, occurred at stations 918 and 1026, in 45 and 182 fathoms, in vast quantities; at 1026, between two and three barrels (probably over 10,000 specimens) came up in a single haul; the elegant star-fish, *Archaster Agassizii* V., occurred in great numbers at station 997, in 335 fathoms: the more common *A. Americanus* V. has often occurred in very great profusion, many thousands being taken at a haul, at several stations. A slender-armed *Amphiura* occurred in very great numbers at station 920, in 68 fathoms, but was seldom met with elsewhere. Many other echinoderms might also be cited, though affording less conspicuous examples. Several very large actinians, among them *Bolocera Tuediæ*, *Urticina nodosa*, and other species of *Urticina*, occurred in great quantities at many stations (924, 937, 938, 998), more than a barrel of them frequently coming up in the trawl. The pretty bush-like gorgonian coral, *Acanella Normani* V., was very abundant at stations 938, 947, 1029. Of the spiny sea-feather, *Pennatula aculeata*, we took over 500 specimens, at station 1025, and nearly a hundred of *Anthomastus grandiflorus* V., at station 1029; both these forms are usually scarce. The coral, *Flabellum Goodei* V., was abundant at 894, 895, 952, 938. The large and curious annelid, *Hyalinœcia artifex* V., remarkable for the very large, quill-like, free tube that it constructs, must be excessively abundant in many places, as at 869, 880, 1025, 1026, 998, 938, for several thousands are frequently taken at a single haul, and sometimes even four or five bushels, as at station 1032. Among Crustacea, such cases are also very common. A species of *Munida* was very abundant at some stations (871, 922, 941), so that 2,000 or more sometimes came up in one haul, and the same is true of several species of shrimp (*Pontophilus brevirostris* Smith, at 865, 871, 878, 941; *Pandalus leptocerus* S., at 870, 878, etc.); certain hermit-crabs, as *Hemipagurus socialis* S., at 871, 874, 877, 878, 940, 941, 944; the maioid crab, *Euprognatha rastellifera* Stimp., at 871–4, 878, 921, 941, etc.

One of the most striking instances was the occurrence of

a very remarkable and hitherto rare hermit-crab (*Parapagurus pilosimanus* Smith), with its associated, investing polyp (*Epizoanthus paguriphilus* V.)* which is a true commensal, forming, out of its own tissues, the habitation of the crab; and hitherto it has not been found elsewhere than upon the back of this particular species of crab, which, likewise, has not been found without its polyp. Of these associated creatures we took about 400 couples, at station 947, in 312 fathoms, at one haul. It had previously only been known by a few specimens taken by the Gloucester halibut fishermen, in deep water, off Nova Scotia, and by ourselves, in 1880.

In October, while on the way south, Captain Tanner made an independent trip to the edge of the Gulf Stream, off Delaware Bay (stations 1043–1049). On this trip, many interesting species were obtained, among which were several fine large specimens of *Echinus gracilis* and *Dorocidaris papillata*. A large species of *Fissurella*, and a very large specimen of a rare crab, *Geryon quinquedens* Smith, also occurred.

During the summer, the writer made some observations in regard to the phosphorescence of many species. Among those having strong phosphorescence, were *Pennatula aculeata*; *Acanella Normani*; *Urticina nodosa* (in which it is confined to the tentacles and the smoother, soft portion of the column, near the summit); *Ophiocnida olivacea*; *Ophiacantha bidentata*.

Additional dredging stations occupied by the Fish Hawk, in 1881.

Station.	Locality.	Fath.	Bottom.	Date.	Temperature.	
					Bottom.	Surface.
	Off Martha's Vineyard.					
	N. Lat. W. Long.			1881		
1038	39° 58′ 70° 06′	146	sand & shells	Sept. 21	47° F.	67° F.
1039	39 59 70 06	136	"	"	50	67
	Off Delaware Bay.					
	N. Lat. W. Long.					
1043	38° 39′ 73° 11′	130	sand	Oct. 10	49	65½
1044	38 37 73 12	224	gray mud	"	42½	66
1045	38 35 73 13	212	"	"	40	66
1046	38 33 73 18	104	sand	"	51	66
1047	38 31 73 21	156	"	"	49	66
1048	38 29 73 21	435	mud	"	40	66
1049	38 28 73 22	435	"	"	40	66

* *Epizoanthus paguriphilus* Verrill, sp. nov. Polyps few and very large, stout, with broad, swollen bases, arising from a very thick, smooth, lubricous, gray or mud-colored, translucent basal cœnenchyma, which at first invests small univalve shells, occupied by *Parapagurus pilosimanus*, but finally grows far larger than the shell and eventually absorbs it. Disk broad, larger than column; tentacles numerous, rather long, light orange. Breadth of colony, 2 to 3 inches; height of polyps, in expansion, 1 inch or more; diameter, ·5 to ·7 of an inch.

ECHINODERMATA.

Most of the Echinodermata enumerated last year were again taken this season, in still greater abundance, and several additional species were discovered. Among the latter are four species of *Archaster*, one of which is new ;* one of the curious round sea-urchins with a flexible test (*Phormosoma Sigsbei*) ; large specimens of *Dorocidaris papillata* ; the European *Echinocyamus pusillus* ; three species of Spatangoids (*Spatangus purpureus*, *Brissopsis lyrifera*, both European species, and a *Schizaster*, like *S. canaliferus*) : but the last two were also taken in 1880, though not then enumerated.

The *Astrochele Lymani* V., occurred at 939, 1028, 1029, in abundance, twining its arms closely around the branches of *Acanella Normani* V. It had before occurred off Nova Scotia, in the same way, on this and other gorgonian corals. *Ophiomusium Lymani* Thomson was taken several times, in 238–500 fathoms. Several new ophiurans were taken, some of which have not yet been fully examined ; and at least one undescribed holothurian.

Schizaster canaliferus L. Agassiz (? variety).

A number of specimens of this singular *Schizaster* have been taken at several stations, in 65–130 fathoms. It is closely related to the Mediterranean form, *S. canaliferus*, and to the species, *S. Orbignyanus*, recently described from the Gulf of Mexico, by Mr. A. Agassiz. Some of the specimens were sent to Mr. Agassiz, who thought them allied to the last named species, but as he had no time to study them carefully, he kindly forwarded specimens of *S. Orbignyanus* to me, for comparison.

My specimens agree exactly with *S. canaliferus*, in form of test, in the shape of the petals, and in the peripetalous fasciole, except that the latter runs directly across the posterior interambulacrum. It differs from both the forms named, in having the lateral fascioles more or less imperfect or abortive on the sides, though distinct below, where they join the subanal fasciole, which is like that of *S. canaliferus*. In some specimens the lateral fascioles, although extremely narrow and faint, can be traced to the peripetalous fasciole, but in many cases it entirely fades out before reaching it. The anal area is usually round, or but slightly elliptical. From *S. Orbignyanus* it differs, also, in having the lower side more convex and the posterior end more swollen and rounded ; in having the anterior furrow shorter, broader and deeper ; in having shorter antero-lateral petals,

* These species are *A. arcticus* Sars, 183–310 fathoms ; *A. tenuispinus* D. and K., 388 fathoms ; *A. mirabilis* Perrier (?), 310 fathoms ; and *A. Bairdii*, sp. nov., 388 fathoms.

more abruptly bent near their origin; and in having shorter and more ovate posterior petals.

I am, therefore, disposed to consider this a geographical variety of *S. canaliferus*, with which it agrees better than with *S. Orbignyanus*. The latter may also eventually prove to be only a more divergent form of the same species. The variation in the lateral fascioles is a very remarkable one, for this is usually regarded as a generic feature. It approaches *Periaster*.

***Brissopsis lyrifera* Agassiz.**

A large specimen from station 921, after immerson for a short time in alcohol, had the test greenish black above, dark brown beneath, spines dark olive-green. Length, 71mm; breadth, 65; height, 46mm.

Phormosoma Sigsbei A. Agassiz, Bulletin Mus. Com. Zool., viii, p. 75, 1880.

A specimen from station 1029, after being in alcohol a few hours, had the test pale orange-brown above, with a darker orange-brown skin beneath; sutures, tubercles and areas whitish; shell pale salmon beneath the skin. Dorsal spines very slender, few and small toward the center, glassy, delicately fluted and finely spinulose, whitish, faintly tinged with orange; beneath, the spines are larger and longer (12mm and more); tubercles large, with deep areas. Diameter of test, 80mm; height, 18, in the flattened state.

***Dorocidaris papillata* A. Agassiz.**

Our specimens are near the variety *abyssicola*. The long spines appear nearly smooth to the naked eye, but are finely fluted and minutely spinulose; they increase gradually in size for a short distance and then taper very gradually to the truncate or slightly excavated tips; the ventral spines are clavate and truncate, with the distal half strongly sulcated; those near the mouth flat and curved. Color of test and small spines, pale pink; large spines, at base, mostly pale pink above, with three or four broad, faint bands of dull greenish brown; scattered spines (probably reproduced), are dark purplish brown; ambulacral zones and sutures, greenish. Diameter of test of largest specimen, 65mm; height, 45; length of largest spines, 80; their diameter, 6mm.

***Archaster Bairdii* Verrill, sp. nov.**

Disk, broad; arms, broad at base, tapering rapidly to slender tips; the interbrachial spaces have nearly the form of a segment of a circle. Lesser to greater radii, as 1 : 2·20–2·38. The abactinal surface is covered with rather large (1·3–1·6mm), regular, well-

defined paxillæ, those toward the center decidedly larger, each surmounted by a regular rosette of short, bluntly rounded, not very small spinules, which, on the larger paxillæ, form a central cluster of 12 to 20 or more, with a regular circle of slightly larger ones around the edge; these rosettes appear more or less hexagonal, and decrease in size toward the margins and on the arms. The dorsal area of the arms is wide at base, but narrow distally. Marginal plates about 20 on each side of the arms, above and below, rather large, not very convex, evenly covered with rounded granules. Actinal surface with large triangular areas, occupied by regular, rather large, clearly defined paxillæ, with regular rosettes of not very fine, blunt spinules. The adambulacral plates bear, each, a group of about five, rather long, slender, tapering, nearly equal spines, which stand in regular longitudinal rows, the edges of the plates projecting inward but slightly; outside the inner group of spines, there is a rosette of shorter blunt spines, of which the three or four innermost are larger and longer than the outer ones, which are small, like those of the paxillæ. Oral plates not swollen, bordered, on each side by seven or eight, rather stout, vertically flattened spines, and terminated at the inner end by two decidedly longer and stouter ones; their surface bears two regular median rows of seven to nine shorter spinules, and usually a row of three or four small ones between these and the marginal series. Ambulacral feet well developed, with a conspicuous, concave, terminal sucker. Greater radius of one of the largest examples, 38^{mm}; lesser radius, 16^{mm}. Color, when living, light orange.

Station 952, in 388 fathoms. Six specimens.

This handsome species has the form and general appearance of *A. Parelii* and *A. Agassizii.* The latter, of similar size, usually has a rather smaller disk, with longer and less rapidly tapering arms, while the dorsal paxillæ, and especially the central ones, are not one-fourth as large, with much finer and more crowded spinules; the marginal plates often bear a central spine; the ventral paxillæ are more convex, with much finer and more crowded spinules; the adambulacral spines are smaller, finer, and more numerous (8 to 10), with finer spinules outside of them; the oral plates are decidedly swollen, with a crowd of fine spinules over the surface, and with the marginal spines, more numerous, smaller and more acute: it also has large, conical ambulacral feet, with a rudimentary sucker.

A. Parelii agrees nearly with the last in form, but has still longer and more narrowed arms. From *A. Bairdii* it differs in having distinctly smaller, less regular, and more crowded dorsal paxillæ, with more uneven, granule-like spinules; the adambulacral plates project inward over the furrows, and each bears five or six smaller, blunt, rough, marginal spinules in a curved

row, with a group of 10 to 12, or more, smaller, divergent spinules outside of them; the oral plates bear shorter and stouter, round, blunt, marginal spinules; the ambulacral feet have well-developed suckers; the color is dull red, in life.

Ophioglypha aurantiaca Verrill, sp. nov.

Disk large, swollen, nearly round, with small notches, destitute of papillæ, at the bases of the five arms; dorsal surface covered by very numerous, small, imbricated scales, partially concealed by a soft skin; in the central area they are crowdedly arranged around one or more larger central plates; the marginal interradial scales are larger and thicker with a median radial row of two or three still larger ones; ventral scales, convex, unequal, imbricated. Radial shields convex, irregularly subtriangular, with rounded corners and outer edge, as broad as long, separated by a group of three or more imbricated disk-scales. Mouth-shields shorter than broad, with an obtuse inner angle, a nearly straight outer edge, and short, notched, lateral edges. Side mouth-shields long and rather broad oblong, meeting within. Mouth-papillæ very small and irregular, 7 to 9 on each side of each angle, those next to the teeth longer and pointed. Teeth slender, acute. Innermost tentacle-pore large, bordered on the outside by about six small flat scales, on the inner by about four. Arms somewhat rigid, rather short and stout, not seen entire; arm-spines three, the upper one rather long and stout, tapered, the others successively shorter and smaller; two tentacle-scales.

Lower arm-plates rather small, transversely rhomboidal, with rounded lateral angles, the four sides concave, and the distal angle prominent; near the base of the arms the plates are in contact, to a small extent, but farther out they are separated by the lateral plates. Upper arm-plates large, thickened, trapezoidal, toward the base of the arms broader than long, broadest distally, the proximal and distal edges nearly straight: farther out they become longer than broad, and much narrowed proximally. Color, in life, bright orange; in alcohol, white. Diameter of disk, 18^{mm}; its height, 7^{mm}; length of arms (minus tips), from center of disk, 45^{mm}. Off Martha's Vineyard, 192 to 310 fathoms. Specimens of this singular species were sent to Mr. Lyman for examination last year. He considered it an undescribed species. It has no near allies on our coast.

Ophioglypha confragosa Lyman (variety).

This remarkable form was dredged, both this year and last, sparingly, in 238 to 410 fathoms. The identification was made by Mr. Lyman, who was kind enough to compare specimens sent to him, with the type-specimens of his species. His specimens were dredged by the "Challenger," off the La Plata, in

600 fathoms. According to Mr. Lyman, our specimens differ but slightly from the type.

Color, in life, yellowish or grayish white. It is easily distinguished by its rigid arms, with decidedly swollen joints; the conspicuously plated, rigid disk; and by the large, supplementary plate, outside the mouth-shields.

Amphiura macilenta Verrill, sp. nov.

A small species, with very long, slender arms, having three slender, acute arm-spines. Disk, in life, nearly round, often becoming pentagonal in alcohol or when dried; upper surface covered with very numerous, small, rounded, naked, imbricated scales, forming a more or less evident rosette at the center; lower side with more minute scales; radial shields long and narrow, wedge-shaped, the outer ends prominent and in contact, the inner ends separated by a narrow wedge of small scales. Mouth-shields shield-shaped, with rounded corners, rather longer than wide, broadest in the middle, inner angle obtuse; side mouth-shields wide. Mouth-papillæ five on each side of each mouth-angle, unequal in size, mostly obtusely rounded; the innermost one, close to the end of the jaw, is longer and stouter than the rest, obtuse, separated by a slight interval from the next, which is the smallest and most acute; the next two are flattened, the fourth being the broadest; the outermost is small and rounded. Lower arm-plates oblong shield-shaped, longer than broad, with the sides and distal edges nearly straight, and a well-marked proximal angle; toward the base of the arms they are in contact, but farther out are separated by the side arm-plates. Tentacle-scales two, minute, flat; tentacles long and slender. Arm-spines three divergent, nearly equal, a little swollen at base, gradually tapered, acute, about as long as the joints. Upper arm-plates transversely rhomboidal with rounded corners and edges, separated by the side arm-plates, even at the base of the arms. Color, light gray. Diameter of disk, of an average specimen, 4^{mm}; length of arms (minus tips), 60^{mm}.

Very abundant, off Martha's Vineyard, at station 920, in 68 fathoms: also taken sparingly at several other localities.

This has been examined by Mr. Lyman, who does not recognize it as a described species.

SCIENTIFIC INTELLIGENCE.

I. Physics and Chemistry.

1. *On the Vapor-density of the Halogens.*—Victor Meyer has summed up the results of the researches made by himself, by Crafts and by Züblin upon the vapor-density of the halogens. Since Züblin's researches have shown that neither by chemical nor physical means can any different substance be obtained from the vapors of the halogens, it would appear that the diminution of density with rising temperature must be due solely to a dissociation of the molecule into its two atoms. Moreover, this dissociation takes place most readily with iodine and least so with chlorine; a temperature which lessens the density of iodine 50 per cent., causing a diminution of only 16 per cent. in that of chlorine. At high temperatures, therefore, the behavior of the halogens would seem inverted, compared with that at ordinary temperatures. The separation of the atoms from each other in chemical reactions is, under ordinary conditions, most readily effected with chlorine, least so with iodine; while iodine tends strongly to form the molecule I_2, as is seen in the many changes where this halogen is set free. But this abnormality is only apparent; for although hydrogen chloride and ethyl chloride are more permanent bodies than the corresponding iodides, this may very well be due, not to the fact that I has a greater attraction for I than Cl has for Cl, but to the other fact that chlorine has a much stronger attraction for carbon and hydrogen than has iodine. The behavior of the halogens, when heated, then leads to the conclusion, that the attraction of one halogen atom for another similar one follows the same order as its attraction for an atom of any other element. Hence chlorine which is the most active of the three halogens is also the least readily dissociated. Iodine which forms weak molecules with hydrogen, ethyl, etc., forms a weak molecule with iodine. Bromine is intermediate in both directions. The author's experiments have also shown the dissociation of the molecules P_4 and As_4 toward P_2 and As_2. Ferrous chloride vapor, which at low temperatures is Fe_2Cl_4, is $FeCl_2$ at high ones.—*Ber. Berl. Chem. Ges.*, xiv, 1453, July, 1881.

G. F. B.

2. *On an Air-thermometer convenient for Chemical purposes.*—The growing necessity for accurately determining temperatures above 350° C., and the absence of any means of doing this, led Crafts in 1878 to propose a modification of the air-thermometer adapted to such uses. Andrews has now described a still simpler form of this instrument. The thermometer part consists of a capillary tube bent twice at right angles, on one end of which is a bulb of about 1 c. c. capacity and on the other a wider tube about 15 cm. long. At the point where the tube widens is a point of black glass to serve as an index, and in the middle of the wide tube is a glass cock. To the end of this wide tube is attached a

rubber tube with two branches, one of which goes to a closed manometer and the other to a rubber bag. The bag, the manometer and the wide tube are filled with mercury. To make an observation, the rubber bag is compressed till the mercury rises to the black glass index and the height of the mercury column in the manometer is noted. The thermometer bulb is then exposed to the temperature to be measured, the column again adjusted and the new height noted. From these data and the constants of the instrument, the temperature may be calculated. With this apparatus, the boiling point of sulphur was found to be 447°, that of phosphoric sulphide 527°, and that of phenyl phosphate 407°.—*Ber. Berl. Chem. Ges.*, xiv, 2116, Oct., 1881. G. F. B.

3. *On the existence of Phosphorous oxide.*—Reinitzer has examined the product obtained when phosphorus is burned in a limited supply of air, which product is stated in the books to be phosphorous oxide, P_2O_3. This body, when dissolved in water under suitable conditions, affords a gold-yellow solution which coagulates gradually on standing but at once on being heated to 80°, and possesses the properties of Leverrier's solution of his phosphate of phosphorus oxide. A study of this solution showed that the yellow phosphorus compound which it contained was a true colloid in whose molecule the phosphorus and the oxygen exist in the ratio 2 : 3, so that provisionally the formula $(P_2O_3)_m (H_2O)_n$ may be assigned to it. Being a colloid body dialysis furnished a means of obtaining it pure. In this condition, it reacts perfectly neutral, and its dilute solution, like that of other colloids, is not coagulated by boiling, but only by the addition of acids or saline bodies. To the product obtained by combustion, then, the author assigns the formula P_2O_3 or better P_4O_6. But it cannot be considered as the anhydride of phosphorous acid since its aqueous solution reacts neutral and contains a yellow colloid.—*Ber. Berl. Chem. Ges.*, xiv, 1884, September, 1881. G. F. B.

4. *On the Preparation of spontaneously inflammable Hydrogen phosphide.*—Brössler has re-examined H. Davy's statement that the action of zinc upon dilute sulphuric acid in presence of granulated phosphorus, produces spontaneously inflammable phosphine, Dumas in 1826 having asserted that the gas evolved was hydrogen, mixed, when the solution was heated, with phosphorus vapor. Brössler confirms Davy's assertion and finds that when some pieces of common phosphorus are placed in a mixture of dilute sulphuric acid and zinc, a regular evolution of gas takes place forming bubbles on the surface which break and ignite spontaneously, giving a brilliant light and a white smoke. The reaction is most satisfactory when the liquid has a temperature of 40° to 50° C., though after it has once commenced it continues even at the temperature of 20°. The gas evolved is readily absorbed by solution of copper sulphate. The author finds the same result to take place when potassium hydrate solution acts on zinc and phosphorus at 60° C. The hydrogen phosphide evolved by the action of hydrochloric acid upon tin in presence of phosphorus is the ordinary variety

not spontaneously inflammable. But upon the addition of a few drops of nitric acid to the mixture the gas inflames spontaneously. —*Ber. Berl. Chem. Ges.*, xiv, 1757, Sept., 1881. G. F. B.

5. *On Ammonium tribromide.*—Roozeboom finds that when to a saturated solution of ammonium bromide, sufficient bromine is added to form H_4NBr_3, and the whole is placed over sulphuric acid for a few days, large prismatic crystals are formed, having the color of potassium dichromate. The heat of their formation is considerable. When a solution of 9.8 grams ammonium bromide in 13·93 grams water is mixed with 8·39 grams bromine, the temperature rises from 20° to 28·6° C. At ordinary temperatures the crystals lose the excess of bromine in from one to two hours; at 50°, in ten minutes. They are not hygroscopic and dissolve readily in water. By drying the crystals in an atmosphere of bromine, they were prepared for analysis. This was effected: 1st, by estimating the loss of weight at 100°; and 2d, by titrating the iodine set free when a weighed portion of the tribromide was put into a solution of potassium iodide. The results confirmed the formula H_4NBr_3. No dibromide appeared to be formed, but from the continued solution of the bromine with additional evolution of heat, the author infers the existence of a pentabromide, H_4NBr_5.—*Ber. Berl. Chem. Ges.*, xiv, 2398, Nov., 1881. G. F. B.

6. *On the Petroleum of the Caucasus.*—Beilstein and Kurbatow have continued their examination of the petroleum found in the Caucasus and have now given the results of their investigation of the oil from Zarskije Kolodzy, in Tiflis. The wells there belong to Siemens & Halske of Berlin, from whom the samples examined were obtained. This petroleum is much lighter than that from Baku and yields a larger quantity of volatile fractions. Three of these were at first obtained, boiling respectively between 30°–35°, 70°–75° and 95°–100°. The first fraction consisted of pentane, and was a mixture of nearly equal parts of normal pentane and isopentane. From the second fraction hexane was isolated; but though the boiling point was correct, analysis showed a deficiency of hydrogen and the specific gravity was too high. Suspecting the presence of the addition-products of the aromatic series corresponding to the formula C_nH_{2n}, the liquid was treated with bromine and with concentrated nitric acid in order to destroy them. The suspicion was confirmed by the fact that after this treatment the liquid possessed all the properties of normal hexane. The third fraction consisted of heptane, from which, by treatment with fuming sulphuric acid, traces of benzene and toluene were obtained. It would therefore appear that the petroleum from Central Caucasus, unlike that from the Caspian Sea, consists essentially of the hydrocarbons C_nH_{2n+2}, like American petroleum, but contains small quantities of the aromatic hydrocarbons C_nH_{2n-6} and their addition-products C_nH_{2n}. Treatment of the crude petroleum with nitric acid of 1·52 sp. gr. gave volatile crystals, which were obtained in relatively greater quantity from the fraction boiling

between 40° and 50°. Recrystallized from alcohol, they appeared as brilliant broad needles, fusing at 95°–96°, insoluble in water but easily soluble in boiling alcohol, in ether, petroleum naphtha, carbon disulphide, etc. On analysis they gave the formula $C_4H_8(NO_2)_2$ which is that of dinitrobutane.—*Ber. Berl. Chem. Ges.*, xiv, 1620, July, 1881. G. F. B.

7. *On the reactions of Chinoline.*—The antiseptic and antipyretic properties of chinoline having led to its extensive introduction into commerce, DONATH has given the following reactions of this base, by which its presence may be recognized: (1) Chinoline salts in aqueous solution are precipitated milky-white by alkali-hydrates. The precipitate is difficultly soluble in excess, but readily soluble in ether, benzene, alcohol, less readily in CS_2, chloroform and amyl alcohol. Sodium carbonate precipitates the solution white with evolution of carbon dioxide. (2) Ammonia precipitates chinoline salts, white, the precipitates being pretty easily soluble in excess. (3) Iodine in potassium iodide solution (7 parts KI, 5 parts I in 100 H_2O) produces a red-brown precipitate, insoluble in hydrochloric acid. Delicacy 1 : 25000. (4) Phosphomolybdic acid (10 parts sodium phosphomolybdate in 100 water made strongly acid with nitric acid) gives with a chinoline solution acidulated with nitric or hydrochloric acid, a yellowish white precipitate easily soluble in ammonia. Delicacy 1 : 25000. (5) Picric acid (1 part to 100 water) gives a yellow amorphous precipitate, soluble in alcohol, difficultly in hydrochloric acid, easily with a reddish-yellow color in potassium hydrate. Delicacy 1 : 17000. (6) Mercuric chloride (5 parts to 100 water) gives a white flocculent precipitate, readily settling, soluble in hydrochloric acid, difficultly in acetic acid. Separated from dilute solutions in crystalline needles. Delicacy 1 : 5000. (7) Potassium-mercuric iodide (5 parts KI, 1·4 parts $HgCl_2$ and 100 parts H_2O) gives a yellowish-white amorphous precipitate, which on the addition of hydrochloric acid, is converted into slender amber-yellow needles. This reaction is characteristic and its delicacy is 1 : 3500. (8) Potassium ferrocyanide produces a yellow color, and on the addition of a mineral acid, a reddish-yellow amorphous precipitate falls which soon becomes crystalline. Delicacy 1 : 1000. (9) Potassium dichromate, carefully added, forms fine dendritic crystals soluble in excess of the reagent.—*Ber. Berl. Chem. Ges.*, xiv, 1769, Sept. 1881. G. F. B.

8. *On the theory of the Peptones.*—POEHL has experimentally confirmed a theory of the formation of peptones proposed in 1873 by Eichwald; i. e., that liquid albumen in contact with animal tissues at the temperature of the body is converted into peptone. This he has done not only by repeating Eichwald's experiments, but by extending the statement to albuminates in various states, even coagulated. He believes that all albuminates are converted into peptone by contact with animal and plant tissues. The formation of peptone for example, when lung or kidney tissues act at blood-heat on swollen fibrin takes place as energetically as the action of pepsin. The view of Eichwald that between the

true albuminates and the peptones various transition forms exist, depending simply on various states of hydration, the author has also confirmed by finding that peptone by treatment with dehydrating agents, as alcohol and alkali-salts, is reconverted into precipitable albumen.—*Ber. Berl. Chem. Ges.*, xiv, 1355, June, 1881. G. F. B.

9. *On the existence of Allantoin in Vegetables.*—The young shoots and leaves of trees contain, as is well known, asparagin which comes probably from the splitting up of albuminates. Believing that other nitrogenous bodies ought to be simultaneously formed, SCHULZE and BARBIERI have examined the freshly opened buds of the plane tree (*Platanus orientalis*) for these substances and have found a body apparently identical with allantoin. The young shoots, dried, were extracted with hot water, the extract decomposed with lead acetate, the filtrate freed from lead and evaporated. In 12 to 24 hours, crystals of the new body separated, mixed with asparagin. The latter may be separated by fractional crystallization or by converting it into the comparatively insoluble copper compound. The filtrate from this after removing the copper by H_2S, yields small, brilliant crystals, difficultly soluble in cold water, and giving the well-known mercury and silver reactions of allantoin. Analysis gave the formula $C_4H_6N_4O_3$. The occurrence of this uric acid derivative in the vegetable kingdom is highly interesting.—*Ber. Berl. Chem. Ges.*, xiv, 1602, July, 1881. G. F. B.

10. *Observations upon Klangfarbe.*—Dr. Rudolph König discusses the question of the origin of harmonic tones and partial tones and investigates the connection between *Klangfarbe* and the change of phase of the pendulum movements involved in the production of sound waves. He does not find that tuning forks kept in motion by electrical means and provided with resonators give true or concordant results, and has accordingly constructed a form of siren by means of which the influence of the form of pendulum movement upon the color-tone can be studied without the disturbing influence of resonators. Different forms of sinusoidal curves representing pendulum movements in various phases are cut upon the edge of thin iron rings which are arranged in a conical form upon an axle. These rings can be rotated in front of various blast pipes from a wind bellows and the blast pipes can be directed either upon the summit of the waves or between the elevations. Discussions of the results afforded by this apparatus are given.—*Ann. der Physik und Chemie*, No. 11, p. 369. J. T.

11. W. *Siemens upon the Dynamo-Electric Machine.*—This paper is in a certain sense a reclamation. The history of the development of the dynamo-electric machine is given as far as it relates to the author's investigations. The development of heat in the machine is considered, and it is maintained that the so-called Foucault currents are not the only cause of the heat which is developed in rotating iron armatures. When these armatures are divided into thin plates separated by insulating media, in order to break up the currents of induction, the iron was still very

much heated. This heating is attributed to the sudden reversals of magnetism when the magnetization approaches the maximum of the magnetic capacity of the iron. In the transmission of power by electricity one-half of the useful effect is consumed in the development of heat, and in the development of magnetic effect where it can not be practically utilized. This loss is a serious drawback to the future of the electrical transmission of power. The following considerations should be observed in the construction of dynamo-electric machines:

(1.) All disposition of conductors which does not conduce to electro-motor effects should be avoided.

(2.) The conductivity of all wires employed to produce such effects should be as great as possible.

(3.) Metals should be arranged so as to avoid Foucault currents.

(4.) The magnetism of the electro-magnets should be fully utilized in the most direct manner.

(5.) The division of the windings of the inducing wires, through which currents of changing direction flow, should be as small as possible; the number of divisions should be made as large as possible to avoid the extra currents which arise with each change of current.

The Hefner von Alteneck machine and the Gramme machine are then discussed from the point of view of the above considerations. The advantages of a new construction of Siemens' armature, in the so-called "Topfmaschine" is dwelt upon, and some measures of the effects of a machine based upon the principle of Unipolar Induction are given.—*Ann. der Physik und Chemie*, No. 11, 1881, pp. 469–483. J. T.

12. *Theory of the rotation of the plane of Polarization of Light.*—Both the ordinary and the magnetic rotation of the plane of polarization of light, E. Lommel considers can be fully explained by the mathematical discussion of the following hypotheses:

(1.) The ether contained between the molecules of bodies has the same properties as the free ether.

(2.) Between the ether and the particles of the body an effect can be produced analogous to those produced by friction, which is proportional to their relative velocities.

(3.) Each particle is affected by an elastic force peculiar to it.

(4.) Each particle is influenced by a resistance proportional to its velocity.

Electrical currents circulating about the molecules must be influenced by the above retarding causes. The mathematical discussion, based upon the above hypotheses, leads to results which agree, on the whole, very well with Verdet's observations on the change of the plane of polarization of light in bisulphide of carbon and in kreosote. The author considers that the divergence of results obtained by Maxwell's formula from the observed results in kreosote, proves its untrustworthiness. Lommel's theory also explains the non-magnetic rotation of the plane of polarization.—*Ann. der Physik und Chemie*, No. 11, 1881, pp. 523–534. J. T.

13. *On the Electrical Resistance of a Vacuum.* — Professor Edlund, of Stockholm, in a memoir presented to the Swedish Academy in April, 1881, has reviewed the results of the long series of experiments made by various physicists during the past century, and bearing upon the question as to the degree of resistance which a vacuum opposes to the passage of an electrical current. His conclusions differ materially from those which have been ordinarily accepted. That, as has been shown by different experimenters, electricity cannot pass through a nearly perfect vacuum, is not questioned, but this is regarded to be due not to a sudden increase in resistance of the vacuum itself, but to the resistance of the passage of the electricity from the electrodes to the surrounding medium. Representing by r_1 the specific resistance in a column of gas of unit length, and by r the resistance to the passage from the electrode to the medium, then the total resistance for a tube of length l will be $r+r_1 l$. Professor Edlund argues that experiments prove that as the medium is rarefied the tension of the electricity needed for a discharge diminishes up to a certain limit (depending upon the distance between the electrodes, the width of the tube, surface of the negative electrodes, and so on), after which it must increase. As r_1, for theoretical reasons, diminishes as the rarefaction is increased, this fact just stated can be explained only by assuming that r increases with the rarefaction; for ordinary pressures r is very small compared with r_1 and can be neglected, and then it follows that the tension needed for a discharge is proportional to the distance. As the pressure is diminished r increases and r_1 decreases, and then the tension necessary for a discharge increases with the distance between the electrodes but in a smaller ratio. When the rarefaction is great, r_1 can be neglected as compared with r, and then the tension is independent of the distance. Professor Edlund states various observations confirmatory of these conclusions and concludes finally that "a vacuum is a conductor of electricity," and, further, that the assumption that the presence of ordinary matter is necessary for the passage of the electrical current cannot be maintained.

14. *An Elementary Treatise on Electricity*; by James Clerk-Maxwell, M.A., edited by William Garnett, M.A. 208 pp. with 6 plates. Oxford, 1881 (Clarendon Press).—The larger portion of the present volume was written by the late Professor Maxwell, some seven years ago, and a part of it was used by him in his lectures on electricity at Cambridge. Unfortunately, other labors caused the author to defer the completion of the work, and at the time of his death only about one-half was entirely finished. The manuscript of a portion of the remainder of the volume, as originally planned, was partially completed, while some important subjects were yet untouched. The volume, as now presented to the public, is, however, far from giving the impression of incompleteness which might be inferred from the above statements, for the editor with wise discretion has filled the vacant

places by selections from Professor Maxwell's well-known larger work on *Electricity and Magnetism*. That this is necessarily accompanied by a loss of strict homogeneity and an occasional sacrifice in the logical order of treatment of individual topics is obvious, but while this makes us regret anew that the author's labors were so prematurely interrupted, it does not seriously affect the value of the book nor prevent it from accomplishing the end for which it was planned. The author's design, as is stated in the fragment of the preface which he left for us, is to "present in as compact a form as possible those phenomena which appear to throw light on the theory of electricity, and to use them each in its proper place for the development of electrical ideas in the mind of the reader." There are many conscientious students of electricity who are unable to master the mathematical methods of Professor Maxwell's larger treatise and yet who desire to obtain an accurate knowledge of the fundamental theories of the subject; to them the present volume, in which mathematical analysis is in general avoided, will be invaluable. In fact it would be impossible for any one, however far advanced, not to gain new ideas or to see old ones in a clearer light, after a careful study of Professor Maxwell's lucid exposition of the subject.

15. *Tables of Qualitative Analysis*; arranged by H. G. MADAN, M.A., F.C.S. 20 pp. 4to. Oxford, 1881 (Clarendon Press).—These tables present a synopsis in an unusually convenient form of the steps through which a student must go in examining qualitatively any ordinary substance, simple or compound. The instructions given under the successive heads are necessarily very brief, so that the student must either already have considerable knowledge or else receive constant assistance from an instructor. A proper use of such tables is very useful in systematizing the knowledge of the student, but it is possible for him to use them too mechanically.

II. Geology and Mineralogy.

1. *International Geological Congress at Bologna.*—The sessions of the International Congress began at Bologna on the 26th of September and continued for one week. The following results of the Congress are taken from a report of the Secretary, M. G. DEWALQUE, of Belgium, published in the Proceedings of the Geological Society of Belgium.

With regard to geological maps, it was decided that a chart of Europe should be published, on 49 sheets, the scale 1: 1,500,000. The chart is to be executed at Berlin under the direction of MM. BEYRICH and HAUCHECORNE, assisted by an international committee of four members from other countries, M. MOSISJOVICS for Austria, M. DAUBRÉE for France, Mr. TOPLEY for Great Britain, M. GIORDANO for Italy, and M. DE MÖLLER for Russia, with M. RENEVIER, of Switzerland, as Secretary.

The subject of the nomenclature for the series of geological formations was also considered and the following conclusion reached.

That for the highest division the term Group be used; that the term for the next lower range of subdivisions be System; for the third, Series (Section in French, Abtheilung in German); for the fourth, Stage; that for the lowest, Assise or Couche in French. Formation was not adopted for either of the higher subdivisions because it is so often used with reference to mode of origin, and also for rocks of a kind without reference to age; and Terrain, because it could not be introduced into the German and Russian languages. By the above, the science will have a Paleozoic *group*, a Silurian *system*, a Trenton *series*, and so on.

The corresponding terms having reference to time in geological history that were recommended by the Congress are, in descending order, Era, Period, Epoch, Age. The position of the subdivision *Age* is not well chosen. In English if it is desired to express the idea of indefinite time, we say the *ages* of the past—periods having limits, and epochs being strictly times of the occurrence of particular events; and it is hence hardly practicable to apply the word Age to a subdivision of an Epoch in Geology.

It was recommended that the scale for a chart of Central Europe be 1:500,000. It was proposed also that in the coloring of geological maps the colors which shall be used on the geological chart of Europe be those as nearly as possible that shall hereafter be generally adopted. Rose-carmine will have the preference for the crystalline schists unless shown to be of Cambrian or later age; violet for the Triassic, blue for the Jurassic, green for the Cretaceous, and yellow will be reserved for the Cenozoic group. The notation in letters on the map will be based on the Latin alphabet; the letters used will be the initials (capital) of the name of the system; and an additional letter or numeral for subdivisions of the system, the numbering starting from the oldest included subdivision. For eruptive rocks the same rule will be followed, except that the Greek letter will be employed in place of the Latin.

The directors of the International chart of Europe will meet at the extraordinary session of the Geological Society of France in 1882, and that of the Helvetic Society of Natural Sciences in 1883, in order to explain the condition of their work; and the two Committees of the International Congress will also be present.

Some general rules also with regard to nomenclature were adopted: one that priority beyond the 12th edition of Linnæus's Systema shall not have authority; and another—which will be questioned by many, though good in purpose and in its consequences—that, in future, priority for specific names shall not be irrevocably acquired unless the species shall have been not only described *but also figured.*

The third meeting of the Congress will be held in Berlin in 1884.

2. *Notice of the discovery of a Peeilopod in the Utica slate formation.*—Through the courtesy of my friend, Rev. William N. Cleveland, of Holland Patent, Oneida County, New York, I

am able to call attention to the discovery of the remains of a large *Pœcilopod* in the Utica slate, north of that village. The remains consist of a large endognathary arm of seven or nine joints, provided with long backward curving sabre-like spines, and a portion of a thoracic somite, probably one-half of the ventral surface of the anterior somite. For this species I propose the name *Eurypterus? Clevelandi*, n. sp., and will give a detailed description with figures of the specimens, in a future number of the Journal.

C. D. WALCOTT.

New York, Jan. 10, 1882.

3. *Coal-Field near Cañon City, Colorado.*—Professor J. J. STEVENSON has described, with detailed sections, this valuable coal-field in a paper published in the Proceedings of the American Philosophical Society for October 7, 1881 (p. 505). It occurs in a small area of Laramie rocks lying along the eastern foot of the Greenhorn Mountains. In a generalized section of the beds thirteen coal beds, from six inches to six feet in thickness (numbered A to M), alternate with shale and sandstone. At the Cañon City Coal Company's shaft, at Rockvale, there are coal beds, A to H, in a thickness of 341½ feet. The sandstone above No. H at some places contains the fucoid *Halymenites major* in great abundance; and this fossil occurs in other localities in the sandstone of the same horizon, and occasionally also at the base of the series; the thickness of the beds between the upper and lower limits is over 400 feet. Professor Stevenson states that he had before found the same fossil abundantly (this Journ., III, xvii, 370), along with dicotyledonous leaves, in a sandstone shown by other fossils to be of the Fox Hills group, and that he had also found the fucoid in a sandstone, 60 to 80 feet thick, of the Trinidad coal-field of Southern Colorado and Northern New Mexico, but not below or above this sandstone; and he had recognized the bed as marking the base of the Laramie group. The sandstone occasionally holds a coal bed, and at one place contained a *Cardium*-like mollusk, too imperfect for determination.

4. *The Paleolithic Implements of the Valley of the Delaware.* 25 pp. 8vo. Proc. Boston Soc. Nat. Hist. for Jan. 19, 1881.—This pamphlet is a collection of short papers on the Delaware Valley paleolithic implements, severally by Messrs. C. C. ABBOTT, the discoverer of them, H. W. HAYNES, G. F. WRIGHT, LUCIEN CARR and M. E. WADSWORTH, with concluding remarks by F. W. PUTNAM. Mr. Putnam closes his remarks respecting these very interesting discoveries and his own visit to the locality, as follows:

"As Dr. Abbott has stated, in his historical summary of the discovery of the implements in the gravel, it has been my good fortune to take, with my own hands, five unquestionable palæolithic implements from the gravel at various depths and at different points. The relation of the circumstances under which one of these was found will be sufficient to convince you that the implement was in the position where it was buried by the four feet of gravel which had been deposited over it.

A short distance from Dr. Abbott's house and very near where the Trenton gravel joins the marine gravel, there is a deep gully through which flows a small brook. In this gully the gravel bank is constantly washing away and presenting new surface exposures. After a heavy rain in June, 1879, I visited the spot with Dr. Abbott and his son. Here I noticed a small boulder of about six or eight inches in diameter, projecting an inch or two from the face of the bank, about four feet from the surface of the soil above; I worked the stone from the gravel in which it was firmly imbedded and drew it out. At the back part of the cavity thus made I noticed the pointed end of a stone, and after working it up and down a few times, so as to loosen the gravel about it, I drew out the implement now exhibited.

On the same day I discovered a second specimen in place, eight feet from the surface, and Dr. Abbott's son Richard found another about four feet from the surface. These three specimens were found within twenty or thirty feet of each other, after a heavy shower had made the most favorable conditions for their discovery. A long continued search, on several following days, at various places along the gravel bluff, failed of success in finding other specimens in place, although several were obtained from the talus. This shows how seldom the implements are likely to be found, and it may be from this cause that some unsuccessful hunters have doubted the occurrence of the implements in the gravel. Certainly the evidence that has been brought forward to-night will clear away all doubts as to the importance and reliability of Dr. Abbott's discoveries and investigations, which have proved the former existence of paleolithic man in the valley of the Delaware."

5. *Bryozoans of the Upper Helderberg Group*; by JAMES HALL. 36 pp. 8vo. Read before the Albany Institute, March 29, 1881. Albany, 1881.—This paper is an abstract of the section on Bryozoans of the Upper Helderberg and Hamilton beds in the Thirty-third Report upon the State Museum of Natural History, made in January, 1880, which has not yet been published.

6. *Tertiary of the Eastern and Southern United States.*—ANGELO HEILPRIN has several important articles on the Tertiary of Eastern North America and its fossil mollusks in the Proceedings of the Academy of Natural Sciences of Philadelphia for the years 1880 and 1881.

7. *Cambarus primævus, a Cray fish, from the Lower Tertiary beds of Western Wyoming*; by A. S. PACKARD, Jr., with a plate. Bull. U. S. Geol. and Geogr. Survey under F. V. Hayden. Vol. vi, No. 2.

8. *American Museum of Natural History* (Central Park, New York). Bulletin No. 1.—This first number of the Bulletin of the American Museum contains three handsomely illustrated and valuable papers, by the paleontologist of the Museum, Mr. WHITFIELD—On a new Crinoid from Burlington, Iowa; On Dictyophyton and new allied forms from the Keokuk beds; and Observa-

tions on the purposes of the embryonic Sheaths of Endoceras, and their bearing on the origin of the siphon in the Orthocerata.

9. *Petroleum in the Northwest Territories of British America, on the Athabasca and elsewhere.*—A paper on this subject, by Dr. R. Bell, is contained in the Proceedings of the Canadian Institute, new Ser., i, 225, 1882.

10. *Traité de Géologie par A. de Lapparent*, Ancien Ingénieur au Corps des Mines, Professor à l'Institut Catholique de Paris. Paris (F. Savy).—This treatise on geology, by M. A. de Lapparent, the associate of Delesse in the preparation of his annual Revue de Géologie, is now in course of publication, only 480 pages having thus far reached this country. This portion, making fascicules 1 to 3, is occupied with the physiographic and dynamical parts of the science. The author has laid out a broad scheme, and so far as completed, the work promises to be quite full and thorough in its treatment of its subjects. After a general introduction, it takes up "Terrestrial Morphology" under the heads of morphology proper and physiography, in which are presented many details from terrestrial physics. Book Second has the title "External Terrestrial Dynamics," and extends to page 366; and Book Third, that of Internal Terrestrial Dynamics. The last treats of the earth's interior temperature, volcanoes, and related topics, and is not finished with the close of fascicule 3. The author has drawn his illustrations for his excellent treatise largely from his own country, yet ranges widely also for illustrations of the subjects.

11. *Jelly-like Hydrocarbon from Scranton, Pennsylvania.*—The jelly-like, carbonaceous mineral, resembling dopplerite, the occurrence of which in a peat bog at Scranton, Pennsylvania, was described by Mr. T. Cooper, (see this Journal, December, 1881, p. 489), has been further investigated by Professor H. C. Lewis, of Philadelphia. The substance, as previously stated, forms thin veins in the muck at the bottom of the peat bog. It is black in color, and when first taken out it is jelly-like in consistency. On exposure to the air it becomes tougher and elastic, somewhat like India-rubber. When in this condition a thin slice can be cut by a knife; it is then seen to be brownish-red by transmitted light, and nearly homogeneous. When completely air-dried it is brittle and nearly as hard as coal and resembles jet, having a brilliant resinous luster and conchoidal fracture; its specific gravity is 1·032. Before drying it burns slowly in a Bunsen burner and without flame, but when dry it burns with a clear, yellow flame. It dissolves partly in hot alcohol, but wholly in caustic potash, even in the cold. An analysis by Mr. J. M. Stinson, of the Pennsylvania Geological Survey, of material dried at 100° C., gave:

C	H	N	O	Ash
28·99	5·17	2·46	56·98	6·40=100·00

Analysis of the dry separated material gave—

Volatile matter,	72·19
Fixed carbon,	21·41
Ash,	6·40
	100·00

The empirical formula calculated is $C_{10}H_{22}O_{16}$, which requires C 30·15, H 5·53, O+N 64·32=100.

In physical characters this substance very closely resembles the dopplerite of Haidinger, from Aussee (see Dana's Min., p. 749), but is different in composition. Similar jelly-like hydrocarbons have been described by others. Lewis suggests that these jelly-like hydrocarbons may be grouped together under the name *phytocollite* (=plant-jelly), but the new name seems very unnecessary.—*Am. Phil. Soc. Philadelphia*, Dec. 2, 1881.

12. *Brief notices of some recently described minerals.*—Bergamaskite is a variety of amphibole remarkable as containing no magnesia. It occurs in a quartzose hornblende-porphyry from Monte Altimo, Province of Bergamo, Italy. Forms acicular crystals vertically striated, with prismatic cleavage at an angle of 124°. G.=3·075. An analysis gave: –($\frac{3}{2}$) SiO_2 36·78, Al_2O_3 15·13, Fe_2O_3 14·46, FeO 22·89, CaO 5·14, MgO 0·93, Na_2O 4·00, K_2O 0·42, loss 0·25=100.—Lucchetti in Z. Kryst., vi, 199.

Litidionite.—E. Scacchi describes blue lapilli from Vesuvius, consisting of a white earthy substance with a glassy-blue crust. An analysis gave: SiO_2 71·57, CuO 6·49, FeO 4·02, K_2O 10·92, Na_2O 6·78=99·78. Fuses easily; the nucleus, consisting of augite, olivine, etc, is infusible. The author on the ground of the fusibility regards the substance as a mixture of quartz and the carbonates of potassium and sodium. Obviously the name given does not apply to any definite mineral species.—*Rend. Accad. Napoli*, Dec., 1880.

Nocerine.—Announced by A. Scacchi as occurring in volcanic bombs in the tufa of Nocera. Found in white acicular crystals referred to the rhombohedral system. In composition regarded as a double fluoride of calcium and magnesium. Associated with fluorite, some brown crystals referred to amphibole, and minute hexagonal crystals perhaps microsommite. The exterior of the bombs is covered with mica.—*Accad. Linc. Trans.*, III, v, 1881.

Melanotekite.—Massive, cleavable in two directions. H.=6·5. G.=5·73. Luster metallic to resinous. Color, black to blackish-gray. Opaque. Analysis gave: SiO_2 17·32, Fe_2O_3 23·18, PbO 55·26, CuO 0·20, FeO 0·75, MnO 0·69, CaO 0·02, MgO 0·59, K_2O 0·24, Na_2O 0·54, BaO 0·11 (?), Cl 0·14, P_2O_5 0·07, ign. 0·93=100·04. The calculated formula is $Pb_2Fe_2Si_2O_9$. Described by G. Lindström as occurring with native lead, magnetite and yellow garnet at Longban, in Wermland, Sweden. This locality has previously furnished two other silicates of lead—hyalotekite and ganomalite.—*Öfv. Ak. Förh. Stockholm*, xxxv, 6, p. 53.

13. *Artificial Enstatite and Chrysolite.*—M. St. Meunier has recently succeeded in forming artificially a variety of minerals by

exposing the metal, a silicate of which is to be formed, when at a red heat, to the vapor of water and that of silicon chloride. This method is regarded by the author as of especial interest as imitating the conditions realized in the natural formation of the primitive minerals of which we have examples in various types of meteorites. He has, for example, succeeded in producing enstatite, a common mineral in meteorites, and that in forms which it often there assumes, as, for example, in clusters of needles radiating from a center, showing in a section the characteristic fan-shaped or star-shaped forms. It is in similar forms in meteorites that the imagination of Mr. Otto Hahn has found crinoids and sponges. M. Meunier remarks, with some humor, that it is significant that these supposed fossils can be formed in a porcelain tube heated to redness. By varying the conditions the author has also succeeded in obtaining a pulverulent mixture of chrysolite (peridote), with the enstatite, and he adds that were this powder, together with a nickeliferous iron, cemented together, we should have a rock essentially identical with that of natural meteorites.—*C. R.*, xciii, 737.

14. *Supposed Organic Remains in Meteorites.*—A year since Mr. Otto Hahn published in Germany a work purporting to describe a large series of fossil sponges, crinoids, corals, and so on, identified by the author in some stony meteorites, more especially that of Knyahinya, Hungary. These conclusions are so fanciful and so obviously without foundation in fact, that it would be unnecessary to refer to them except that a recent article has been published in this country in which the discoveries are described in the spirit of the author, and which is calculated to mislead those unfamiliar with the subject. The supposed organic forms seen in thin sections of the meteorite are merely the radiated and stellated forms which the mineral enstatite often assumes in meteorites, and which M. Meunier has shown (see above), can be imitated successfully. They bear the same relation to fossil remains that dendrites of manganese oxide bear to vegetable impressions. Professor J. Lawrence Smith, who has done more than any one else to make us acquainted with the various carbon compounds which occur in meteorites, has not long since expressed himself (*Courier Journal* for Nov. 22, 1881, Louisville), very strongly as to the observations of Mr. Hahn. Among other remarks he says: "Were these remains present we should discern carbonate of lime on their interior. The two or three that have any carbonate of lime were discovered and analyzed by myself, and in these cases the carbonate of lime was an accidental constituent of incrustation deposited on the surface after their fall."

It is only simple justice to Mr. Hahn to say that while his conclusions will not be accepted, his memoir is a most valuable contribution to the study of the structure of meteorites. The photographic plates which accompany it are remarkably beautiful and can be studied with profit. It is only the author's interpretation of them which is at fault.

15. *Tabellarische Uebersicht der Mineralien nach ihren krystallographisch-chemischen Beziehungen geordnet von* Paul Groth.—Zweite vollständig neu bearbeitete Auflage. 134 pp. 4to. Braunschweig, 1882. (Fr. Vieweg & Son). — Professor Groth's volume, while modest in its plan, is still a valuable contribution to mineralogy, more especially on the chemical side. It furnishes a list of all well established mineral species, classified according to chemical characters and crystalline form, giving for each its chemical formula, crystalline system, and axial relations. It is intended particularly for the use of students, but will be useful for all who desire to have before them a classification of minerals in clear and concise form. In reviewing the chemical composition of many species the author has often been able to make important suggestions as to the way in which the formula should be written, and in this way he introduces a large number of original ideas which throw light on doubtful points. The relations of the different isomorphous groups of compounds has never been better presented.

III. Botany and Zoology.

1. *Natural History Nomenclature.*—The Zoological Society of France has issued a pamphlet entitled "Règles applicable à la Nomenclature des Êtres Organisés," which it proposes for adoption, and upon which comments are requested. The rules were to be submitted to a Geological Congress held last autumn at Bologna.

The rules are brief and simple, and occupy less than three pages. A Report from a committee, by M. Chaper, fills the remainder of the 37 pages. The rules being for both kingdoms of organized beings the opinion of botanists is invited. These rules, proposed in the interest of Zoology, are in such agreement with those practiced in Botany, and especially with those in the digest made by M. DeCandolle a few years ago, that they call for little remark, and that mostly in small particulars. In some cases a sensible recommendation or a preferable rule has, perhaps, been pushed to extremity. For instance, specific names of essential identity of meaning and derivation, but of different form, such as "*fluviorum*, *fluvialis* and *fluviatilis*" are not allowed in the same genus. The introduction of such names may well be objected to, but if two of them had found their way into a large genus of plants, botanists would hardly regard it as a case of double employment of the same name.

Specific names from persons are required always to be nouns in the genitive. Botanists have always used the adjective form more or less, and we see no reason why they should forego it. *Lamarckianus* is as good as *Lamarckii* and better than *Lamarcki*, to which these zoologists would restrict us. For their rule goes on to require that all such words (excepting those which have been actually used and declined otherwise in the Latin language) shall

make their genitive in a single *i*. We think that we have seen this rule applied in some zoological works, and with cacophonous results. Surely the ear must judge whether a barbarous name shall be latinized in *us* or *ius*. In many cases the choice may be nearly indifferent; in others by no means so. Who would write *Pecki* or *Beckl* in place of *Peckii* or *Beckii?* Fortunately the laws before us direct that such specific names shall be written with either a small or a capital initial according to the rule generally followed in writing. So we need not follow the custom which in England certain zoologists have forced upon one botanical work, and other zoologists are adopting in this country, which would require us to write *peckii*. It is strange that any one could wish to have a mechanical and senseless uniformity override all other considerations.

By one rule, the name of an author when appended to that of a species must always be printed in a different type from that of the species. As the omission of this causes no confusion in writing, it might seldom cause any in print. But ordinarily the reference, of which this name is the abbreviation, is in different type from the name which precedes. It is hardly a matter to prescribe by law.

That the names of families should always end in *idæ* may be practicable in zoology, but hardly so the rule against homonyms, viz: that the name of a genus which has been reduced to a synonym shall never again be used as such in the same kingdom, nor a specific name so reduced be ever used again in the genus. It is laid down, also, that no name once published shall ever be discarded on account of its impropriety. That surely depends on the degree of impropriety.

The *Exposé des Motifs* in the Report by M. Chaper sometimes takes questionable ground; in one place it seems to contradict the rule last referred to, declaring that the name *Novæ-Hollandiæ* must be changed to *Neo-Batavus*, first, because that is the proper Latin form, and second because all specific names from countries should be adjectives,—which is quite as unnecessary as their other rule that all names from persons shall be genitives.

The Report brings out a point which the rules do not pronounce upon, viz: that the zoologists take the ground that the name of a species transferred by a later writer to some other genus shall still be followed by the name of the original founder, thus making species override genus in importance, and confusing chronology. We have so fully and repeatedly expressed our opinion on the matter in this Journal that we need not farther refer to it here. The last adopted laws of botanical nomenclature and the practice of almost all phænogamous botanists agree in rejecting this innovation. The reduction of the rank of genus by zoologists to the last degree of analysis gives some excuse for the practice, and the practice seems likely to facilitate the degradation.

Naturally we have indicated only points in which the proposed rules do not harmonize with the received botanical code. A. G.

2. *Maximowicz, de Coriaria, Ilice et Monochasma*, etc. A quarto paper in the Mém. Acad. St. Petersb., 1881. pp. 70, and four plates.—A full discussion and monograph of *Coriaria*, and the conclusion reached that this monotypical genus should stand next to the *Simarubaceæ*. *Ilex* is similarly discussed as to the character and extent of the genus, is divided into four sections in a somewhat new way, seemingly with excellent judgment; but *I. Cassine* falls to one section and *I. Dahoon* and *I. myrtifolia* to another. *Monochasma* is a new Chinese genus near to *Bungea*, and to *Schrabera* is assigned a character for better distinguishing it from *Siphonostegia*, viz: that the placentæ become free from the valves before the maturity of the capsule. A. G.

3. *Ueber sogenannte Compasspflanzen.* By Professor E. Stahl. —In this paper, which is an extract from the *Jen. Zeitschrift*, Stahl gives the result of his experiments with *Lactuca Scariola* and *Silphium laciniatum*, for the purpose of ascertaining the conditions which cause the leaves of the plants named to assume a meridional position. In the case of the *Silphium*, which is the common Compass-plant of the Western States, the fact that the leaves point in a northerly and southerly direction has long been known, but in the case of *Lactuca Scariola*, although it had been observed that the leaves were often vertical, Stahl was the first to notice that they generally stood in meridional plane. In both plants, the peculiar position of the leaves is best seen when they grow in unsheltered places, exposed to bright sunlight; while when crowded together, or growing in the shade, the leaves generally assume the common horizontal position. The leaves of *Lactuca* are arranged on the stem in the $\frac{2}{5}$ order. Those on the north side of the stem become vertical by a twisting of the petiole, the upper surface of the leaf facing the east. Those on the south side by a similar twisting become vertical with the upper surface facing the west. The leaves on the east and west side of the stem do not exhibit any torsion of the petioles, but they become upright with their upper surfaces approximated to the stem. Stahl took two plants growing in pots and placed one where it would be exposed to direct sunlight from 10 o'clock until 3, and kept in the dark for the rest of the day; the other was placed so that from sunrise until 10 o'clock and from 3 o'clock until sunset it was exposed to the sunlight, but from 10 to 3 was in the dark. In the first case the leaves did not assume a meridional position, but in the second case they did. That the meridional position is produced by the sun when near the horizon is clearly shown by the following experiment. A pot with several young plants was placed in a window facing the north, where the plants received direct sunlight a few hours after sunrise and before sunset. In this experiment the leaves bent toward the north with their upper surfaces turning either to the east or to the west. The pot was then placed farther back in the room, so that the plants were not exposed to the direct sunlight, and the leaves then assumed a position at right angles to the diffuse light from

the window. Stahl concludes that the meridional position of the leaves of *Lactuca Scariola* is due to the common diaheliotropism observed in most leaves, and that these leaves differ from those of other plants only in their greater sensitiveness to intense light. In *Silphium* there is a torsion of the petioles as in *Lactuca*; and, if the petioles are fastened so that they cannot bend, the blade of the leaf itself twists. Stahl states that a meridional position of the leaves can be seen clearly in *Aplopappus rubiginosus* and to some extent also in *Lactuca saligna* and *Chondrilla juncea*, and he believes that many other examples will be found, especially among the plants of dry and exposed regions. W. G. F.

In a number of the Botanical Magazine, published during the past year, in which the American Compass-plant is illustrated, it is recorded that I noticed, during the previous year, in a plant growing in the Botanic Garden of Harvard University, one leaf in which there was an abrupt torsion of 90° in the middle of the blade. I cannot now say whether or not the basal portion was free to change its direction. A. G.

4. *The Brain of the Cat*, Felis domestica, by BURT G. WILDER, Proc. Amer. Phil. Soc., 1881.—An elaborate memoir occupying 40 pages and illustrated by 4 fine lithographic plates.

IV. ASTRONOMY.

1. *Notation of Comets.*—The Council of the *Astronomische Gesellschaft*, at the recent meeting at Strassburg, recommended that the notation of comets in any year by the letters *a*, *b*, *c*, etc., according to the date of discovery, be given up altogether. There is good reason for the recommendation. The notation I, II, III, etc., according to perihelion passage, is that which it is important to retain after the year has passed. Two notations so similar tend to confusion. Until the order of the perihelion passage is determined the comets can be readily distinguished by the names of their discoverers, adding the date of discovery if necessary, so that the notation by letters is superfluous. H. A. N.

2. *Astronomische Nachrichten, begründet von H. C. Schumacher.*—This veteran Journal has just completed its hundredth volume. Dr. A. Krueger, who has succeeded the late Dr. Peters as Director of the Observatory at Kiel, has also succeeded him in the editorship of the Journal. By an understanding with the Prussian Government the Council of the *Astronomische Gesellschaft* promises assistance and countenance in order that the *Astronomische Nachrichten* shall be the central and leading organ of Astronomical periodical literature. H. A. N.

3. *Washington Observations for* 1877—*Appendix III.*—Professor EASTMAN gives us in this appendix a value of the solar parallax from meridian observations of Mars. In September, 1876, Admiral Davis invited the coöperation of other observatories in making, after a plan prescribed by Professor Eastman, meridian observations upon Mars at the opposition of 1877, for

the purpose of determining the solar parallax. Returns which could be used in the investigation were received from Melbourne, Sydney and the Cape of Good Hope in the Southern, and from Cambridge (Mass.) and Leyden in the Northern Hemisphere.

After the discussion and comparison of the observations, rejecting a very few that are palpably erroneous, Professor Eastman says: "Taking the mean of the remaining *seventy* results from all the stations, with regard to the weights, we have—

$$\pi = 8''\cdot980 \pm 0''\cdot0172.$$

The results from the Melbourne and Cambridge combination seem to indicate either that the value found for π [$9''\cdot1382$] is certainly too great, or that the observations at the first five stations are all affected by a systematic error.

This difference may arise from the method of observing over inclined threads at Cambridge, for the agreement of the results among themselves is very satisfactory; but, whatever the cause of the discrepancy may be, it has not been deemed advisable to employ these values in obtaining the final result.

Omitting the results derived from the Cambridge observations, and also those inclosed in parentheses, and taking the mean of the remaining *sixty* results with regard to the computed weights, we have for a final result—

$$\pi = 8''\cdot953 \pm 0''\cdot019.$$

This value of π is undoubtedly greater than would be assigned by a large majority of astronomers, but it fairly represents what the method will give from such observations as were at hand for this discussion." H. A. N.

4. *Thirty-sixth Annual Report of the Director of the Astronomical Observatory of Harvard College*; by Edward C. Pickering. 16 pp. 8vo. Cambridge, 1882.—Professor Pickering's Annual Report gives a gratifying statement of the present condition of the Harvard Observatory, and of the work which has been accomplished there during the past year. The brief summary of the work done includes: (1) a large number of photometric observations of the eclipses of Jupiter's satellites; (2) observations of stars having singular spectra—the spectra of all the stars north of $-40°$ marked as red or colored in the Uranometria Argentina have been examined in the large telescope, and from this and also some miscellaneous sweeping, a list of about eighty stars having banded spectra has been published; (3) photometric study of variable stars; (4) observations of the comets of 1881; (5) observations with the meridian circle, and (6) with the meridian photometer. The distribution of time signals has been continued under the charge of Mr. F. Waldo until June 1, and since then of Mr. Edmunds; it is stated that the error is believed to rarely exceed two-tenths of a second in clear weather and four-tenths when cloudy, and that the error seldom changes more than two-tenths of a second from one day to the next.

Among the investigations proposed for the coming year are the measurement of the position of the principal lines in the spectra of all banded stars as yet known; also the photometric determination of the brightness of various points on the surface of the moon; the measurement of the light of faint stars, for which a system of standards of brightness has been devised with the coöperation of other astronomers. The new meridian photometer will be used for measuring variable stars and their comparison stars, and also for determining the light of the brighter asteroids.

V. Miscellaneous Scientific Intelligence.

1. *Mining Industries: Paris Exposition*, 1878; by A. D. Hague, Commissioner.—This valuable review of the Mining Industries of the various nations of the globe contains a condensed survey of mining products, mining processes and materials, mining imports and exports, mining regions, ores and ore-deposits, coal fields, diamond fields, etc., consumption of metals, coals, etc.

2. *Were Ancient Copper implements hammered or moulded into shape.*—Professor F. W. Putnam, of Cambridge, Mass., closes a note on this subject in the Kansas City Review for December, with the following statement:

"That copper was used in large quantities by the Indians there is no doubt, and it was also used to a considerable degree by the tribes who erected the burial mounds in the Ohio valley and throughout the southwest, whoever they were; but I have not yet seen a single object made of copper from these sources that I should regard as having been cast; on the contrary, the evidence of hammering, and rolling between stones, is more or less clearly shown in all by the character of the surface and by the distinct lamination of the metal in places, when carefully examined with a lens."

3. *United States Coast Survey.*—Mr. J. E. Hilgard, Chief Assistant in the Coast Survey Department, has recently been appointed Superintendent in place of Captain C. P. Patterson, deceased. Mr. Hilgard is eminently fitted for the position.

3. *Beebe's Four-Place Tables.*—This book contains, in clear type and compact form, the logarithms of numbers with proportional parts, and the trigonometric functions, both logarithmic and natural, at intervals of ten minutes, with their differences. The arrangement is the same as that of Gauss's five- and Vega's seven-place tables, and is therefore the best possible. This feature makes them an excellent introduction to the larger works. A very careful comparison with the standard tables reveals no mistakes. Published by H. H. Peck, New Haven.

Sensation and Pain. by Charles Fayette Taylor, M.D. 78 pp. 16mo. New York, 1881. (G. P. Putnam's Sons).

Opium Smoking in America and China, by H. H. Kane. M.D. 156 pp. 16mo. New York, 1882. (G. P. Putnam's Sons).

Greenwich Spectroscopic and Photographic Results. 84 pp. 4to. 1880.

Bulletin of the Minnesota Academy of Natural Sciences. Minneapolis, Minn. Vol. ii, No. 3, 1881. pp. 37–238.

OBITUARY.

JOHN WILLIAM DRAPER, M.D., LL.D.—The death of Dr. Draper, which occurred on the 4th of January, removes the most renowned investigator in molecular physics and the most encyclopedic author in the circle of American scientists. Although born in England, and trained there in youth, Dr. Draper's life-work and field of labor were in America. Born at St. Helens near Liverpool, May 5, 1811, he had his early education in a Wesleyan school at Woodhouse Grove, where his scientific tastes were developed. His studies in chemistry and physics were afterward pursued under a private teacher, and later at the London University. Following the greater part of his family, he came to this country in 1833, at the age of 22, and in 1836, took the medical degree from the University of Pennsylvania where his thesis on the Crystallization of Camphor under the influence of light, and kindred subjects, was selected by the Faculty for publication. This is the first of a long series of experimental researches on radiant energy. It led to his appointment, in the same year, to the chemical and physiological chair in Hampden Sidney College, Virginia, where he had the opportunity to prosecute other investigations in the same line. These, without effort on his part, brought him, soon after, the appointment to the Professorship of Chemistry and Physiology in the University of New York, where he remained through the entire period of his life. In 1841 he was active in establishing the University Medical College; and he resigned the duties of presiding officer of the Medical Faculty only in 1876. For more than forty years, Dr. Draper was quietly engaged in careful experimental researches in physiology and molecular chemistry, publishing the results of his work in this Journal, the Journal of the Franklin Institute, the American Journal of Medical Science, and in the London Philosophical Magazine. These researches cover a very large range of subjects, but were mostly devoted to a study of the chemical phenomena of light, in both the organic and inorganic world. In 1878 he collected and condensed these researches and published them in a separate volume under the title of "Scientific Memoirs, being Experimental Contributions to a Knowledge of Radiant Energy" (473 pp. 8vo). This volume was noticed at the time of its publication in vol. xvi, p. 390 (1878) of this Journal. It remains a noble monument to his memory, made of the results of labors which have greatly advanced the sum of human knowledge.

Of the substance of the thirty separate memoirs which constitute it the author says: "Among many other subjects treated of in these pages the reader will find an investigation of the temperature at which bodies become red hot, the nature of the light they emit at different degrees, the connection between their condition as to vibration and their heat. It is shown that ignited solids yield a spectrum that is continuous, not interrupted. This has become one of the fundamental facts in astronomical spectroscopy. At the time of the publication of this memoir (1847), no one in

America had given attention to the spectroscope, and, except Fraunhofer, few in Europe. I showed that the fixed lines might be photographed, doubled their number, and found other new ones at the red end of the spectrum. The facts thus discovered I applied in an investigation of the nature of flame and the condition of the sun's surface. I showed that under certain circumstances rays antagonize each other in their chemical effect, and that the diffraction spectrum has great advantages over the prismatic, which is necessarily distorted. I attempted to ascertain the distribution of heat in the diffraction spectrum, and pointed out the great advantages if wave-lengths are used in the description of photographic phenomena. I published steel engravings of that spectrum so arranged. I made an investigation of phosphorescence and obtained phosphorescent pictures of the moon. Up to this time it had been supposed that the great natural phenomena of the decomposition of carbonic acid by plants was accomplished by the violet rays of light; but by performing that decomposition in the spectrum itself, I showed that it is effected by the yellow. Under very favorable circumstances I examined the experiments said to prove that light can produce magnetism, and found that they had led to an incorrect conclusion. The first photographic portrait from the life was made by me. . . . . I also obtained the first photograph of the moon. . . . . When Daguerre's process was published, I gave it a critical examination, and described the analogies existing between the phenomena of the chemical radiations and those of heat. For the purpose of obtaining more accurate results in these various inquiries I invented the chlor-hydrogen photometer, and examined the modifications that chlorine undergoes in its allotropic states. Since in such researches more delicate thermometers are required than our ordinary ones, I entered on an investigation of the electromotive power of heat, and described improved forms of electric thermometers. In these memoirs will be found a description of the method made use of for obtaining photographs of microscopic objects, together with specimens of the results. In a physiological digression respecting interstitial movements of substances, I examined the passage of gases through thin films such as soap-bubbles, and the force with which these movements are accomplished, applying the facts so gathered to an explanation of the circulation of the sap in plants, and of the blood in animals. Returning to an inquiry as to the distribution of heat and of chemical force in the spectrum I was led to conclude, in opposition to the current opinion, that all the colored spaces were equally warm; and that, so far from one portion—the violet—being distinguished by producing chemical effects, every ray can accomplish special changes. This series of experiments, on radiations, is concluded in this volume by an examination of the chemical action of burning-lenses and mirrors."

This is a remarkable series of claims for one investigator to set up on a single line of research. But they were well founded; and

this was substantially affirmed by the report of the Committee of the American Academy of Arts and Sciences, at Boston, which, after an impartial review of Dr. Draper's work, recommended the award by the Academy of the Rumford Medals for the year 1875 (one of gold and one of silver) to Dr. Draper for his "Researches on Radiant Energy."* This was only the sixth award of the Rumford Medal in about sixty years. The previous five awards were (1) to HARE (1839) for the invention of the oxy-hydrogen blowpipe and improvements in voltaic apparatus; (2) to ERICSSON (1862) for his caloric engine; (3) to TREADWELL (1865) for improvements in management of heat; (4) to ALVAN CLARK (1867) for improvements in the lenses of refracting telescopes; (5) to CORLISS (1870) for improvements in the steam engine. This enumeration shows that the award to Dr. Draper was for important *discoveries* in science, while the others, excepting in the case of Dr. Hare, were for *inventions* and *improvements.* It rarely falls to the lot of any one investigator in physical research to add so largely to the triumphs of science over the unknown.

Our admiration, however, of the author's ability and industry is increased, when we review the considerable number of important memoirs which he has contributed to the departments of chemistry, electricity and physiology. We have to regret that the author did not find strength, in his declining years, to give to the world his memoirs on chemical, electrical and physiological topics, some of them hitherto unpublished, of which he says, in the preface to the volume mentioned: "These, for the present, I must reserve." But it is a great satisfaction that he has left, as his literary executors, sons whose names are well known in the annals of science, from whom we may look for the collection of memoirs so reserved. A full list of Dr. Draper's papers, corrected by himself, will be found in the writer's address entitled "Contributions to Chemistry," 1874, pages 78–82.

But Dr. Draper was not simply an experimental investigator of natural phenomena. He was an earnest and also a deep thinker in the department of the philosophy of history and human progress, and his works in this direction were among his most elaborate efforts. He says: "From the study of individual man it is but a step to the consideration of him in his social relations, and this, accordingly, had been done in the second part of my work on Physiology. But the subject being too extensive to be dealt with satisfactorily in that manner, I have published the materials that I had collected in a separate book under the title of 'A History of the Intellectual Development of Europe.'" The view which he aimed to illustrate in this work is that the intellectual progress of nations proceeds in the same course as the intellectual development of the individual; that the movement of both is not fortuitous, but under the dominion of law. His "Thoughts on the Civil Polity of America," his elaborate "History of the American Civil War," in three volumes, and his "History of the Con-

* Proceedings American Academy, II. xi. 313, 325. May 25, 1875, March 8, 1876.

flict of Religion and Science" are all logical sequences of his view of human progress. He remarks, "When I thus look back on the objects that have occupied my attention, I recognize how they have been inter-connected, each preparing the way for its successor. Is it not true that, for every person, the course of life is along the line of least resistance, and that in this the movement of humanity is like the movement of material bodies?" As many may have regarded Dr. Draper as a materialist, and at least as indifferent if not hostile to religion, it is a satisfaction to affirm that he was a theist and a firm believer in a future state of existence for which the present is only a preparation.

For many years Dr. Draper has dwelt in a quiet retreat at Hastings on the Hudson, a few miles from New York City, near the astronomical observatory of his son, Dr. Henry Draper, the well-known astronomer, and surrounded by everything that could minister to the tastes of a veteran in science. Here he quietly surrendered, on the morning of January 4, 1882, a life crowned with the rewards of a long devotion to his favorite pursuits, and honored by the diffusion of his fame through the translation of his more elaborate works into a great number of European and Asiatic languages. His wife died many years before him, leaving three sons and three daughters. All the sons have adopted pursuits of science, kindred to the father's taste, and have made names for themselves now well known in the walks of science.

The funeral of Dr. Draper was attended, January 10th, by a throng of mourners, including delegates of numerous scientific societies with which the deceased had been connected—the Faculties of Medicine and Arts, Science and Law, of the University of New York, and members of the Faculties of the Universities of Vermont and Pennsylvania. The religious ceremonials were observed in St. Mark's Church, in New York, where the remains were brought from the village church at Hastings on the Hudson, and finally found their resting-place in the Greenwood Cemetery, on Long Island. B. S.

Lewis H. Morgan, eminent in American Ethnology and Archæology, died on Saturday, the 14th of December last, at Rochester, New York. He early began his study in his favorite department among the Indians then remaining in Western New York. His published works and memoirs are all the result of extensive research, and gave him the leading place among American archæologists. The most important are "The League of the Iroquois" (1851), "The earliest Systems of Consanguinity and Affinity of the Human Family," published by the Smithsonian Institution in a quarto volume of 700 pages (1873), "Ancient Society, or Researches in the line of human progress from Savagery through Barbarism, into Civilization" (1877), "Houses and House-life of the American Aborigines" (1881); and in another line, the "American Beaver and his Works" (1867). Mr. Morgan was President of the American Association at the meeting in 1880 at Boston.

THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

Art. XIV.—*On the Color Correction of double Objectives*; by Charles S. Hastings.

I. *Review of attempted methods.*

If we call the focal length of two thin lenses in contact P, one of the lenses being made of a material with indices of refraction n, and the other with indices indicated by n', we may write

$$\frac{1}{P}=\varphi=(n-1)\ A+(n'-1)\ B, \qquad (1)$$

where A equals the sum of the curvatures of the two surfaces bounding one lens and B the corresponding sum for the other.

In order that this system may be achromatic it is necessary that P or φ should be invariable with n and n', or in other words that the equations

$$\frac{d\varphi}{dn}=0=A+\frac{dn'}{dn}\ B \qquad (2)$$

$$A=-\frac{dn'}{dn}\ B \qquad (3)$$

should be satisfied. Unfortunately this is in practice impossible, because at present no two varieties of glass are known in which $\frac{dn'}{dn}$ is constant. On the contrary, this coefficient is itself

a function of n and has an infinite number of values, all included in practical cases, however, within limits nearly approached. Thus, since the last equations cannot be satisfied for all values of n, the problem is reduced to finding that value of $\frac{dn'}{dn}$ which substituted in (3) will make the combination the most advantageous one.

The first efforts to find a solution of this problem were attended by one of the most brilliant discoveries in physical optics. Only in objectives of considerable size does the question become of great importance, and as Fraunhofer was the first to attempt such objectives, so he was first confronted with the problem. To solve it he performed an elaborate series of experiments on the optical properties of various glasses, during which he discovered the lines in the solar and certain stellar spectra universally known by his name. Moreover, as it was evident that the accepted value of $\frac{dn'}{dn}$ should depend upon the relative intensity of lights of different refrangibilities, he made a photometric determination of the brightness of the various parts of the solar spectrum. With data thus derived his theoretical method of determining the best value of the coefficient $\frac{dn'}{dn}$ was to deduce various values by observation, multiply each value so obtained by the relative brightness of the corresponding region of the spectrum, and divide the sum of these products by the sum of the numbers denoting the brightnesses. For example, if n_α, n_β, n_γ, etc., are the indices of refraction for the first medium corresponding to the Fraunhofer lines α, β, γ, etc., n'_α, n'_β, n'_γ, etc., the corresponding quantities for the second medium, and q_1, q_2, q_3, etc., are the relative quantities of light contained in the solar spectrum between the lines $\alpha\beta$, $\beta\gamma$, etc., then the accepted value of the coefficient is given by the equation:

$$\frac{dn'}{dn} = \frac{q_1 \frac{n'_\beta - n'_\alpha}{n_\beta - n_\alpha} + q_2 \frac{n'_\gamma - n'_\beta}{n_\gamma - n_\beta} + \text{etc.}}{q_1 + q_2 + \text{etc.}}$$

Fraunhofer found, however, that for a combination of crown and flint glass this method always gives too large a value for $\frac{dn'}{dn}$, that is to say, that an objective so constructed would be notably under-corrected. Nor is it difficult to recognize that the theory is imperfect, for it implies that light of all refrangibilities is of value in the formation of the image exactly in

proportion to its intensity, whereas, in reality, light of the extremes of refrangibility instead of assisting in defining an image is absolutely harmful. Fraunhofer was driven, therefore, to a purely empirical determination of the quantity under discussion; and from his time to the present, the only way for an optician to determine the relative foci of the two components of an achromatic objective is by a laborious process of altering the curves and testing the result until the outstanding color about the image of a bright star is such as *experience* has shown is attended with good definition. A few of the more scientific opticians determine the coefficient by means of prisms instead of lenses, and thus, by a knowledge of the mathematical relations involved, save a great deal of manual labor. Still, even in the case where a pair of prisms combined to form a *diasporometer* is used, instead of a pair of lenses, the accepted value of the coefficient depends upon an exercise of the judgment alone, and hence this process yields no unambiguous solution.

II. *A Theoretical Solution.*

In order to investigate the best theoretical value for the coefficient $\frac{dn'}{dn}$, we may begin by expressing n' either directly or indirectly as a function of n. The most naturally suggested course is to express each as a function of the wave-length of light according to Cauchy's well known formula; but not only is the labor of computing the constants for the necessary three terms of such a formula great, but the accuracy of the expressions thus obtained is very inconsiderable. In another article,* however, I have shown that n' may be expressed, for all cases of practical importance, as a function of n by a simple trinomial of the second degree so that the residuals are smaller than the errors of observation except in cases where very extraordinary accuracy is attained.

We have thus:

$$n' = \alpha + \beta n + \gamma n^2 ;$$

and the equations above become

$$\frac{1}{P} = \varphi = (n-1)\ A + (\alpha - 1 + \beta n + \gamma n^2)\ B \qquad (1')$$

$$\frac{d\varphi}{dn} = 0 = A + (\beta + 2\gamma n)\ B \qquad (2')$$

$$A = -B\ (\beta + 2\gamma n). \qquad (3')$$

The problem is to determine the particular value of n which can be most advantageously substituted in the last equation.

* On Triple Objectives with Complete Color Correction. This Journal, vol. xviii, p. 429, 1879.

This value will be designated as n_0 and the corresponding focal distance as P_0.

To accomplish the solution we must first find a criterion of excellence in an objective. This we may easily do, after defining the sense in which we here use certain terms, as follows:—

Light, for the purpose of this investigation, is defined as that form of radiant energy which affects the retina; its quantity is measured, not by the value of the energy, but by the physiological effect which it is capable of producing.

The *intensity of light of refrangibility n* is measured by the quantity of light contained between the refrangibilities n and $n+dn$ divided by dn. Thus, if q_n equals the quantity of light so defined and ι_n its intensity, then

$$q_n = \iota_n dn.$$

In what follows we shall consider only such light as is given out by a very hot solid body. This light is composite and contains light of all refrangibilities from a little less than that of the Fraunhofer line A to, practically, a little more than that of the line H. We let n_r and n_r represent these limits of refrangibility. Then, if Q is the total amount of light falling upon a given area, e. g. upon an objective, we have evidently

$$Q = \Sigma q = \int_{n_r}^{n_v} \iota \, dn.$$

In this expression ι is an unknown function of n, but we know enough of the properties of this function for the present purpose.

A perfect objective would concentrate *all* the light incident upon it from a distant point in its axis to a very small circular area in the focal plane, which area would be constant for all telescopes of the same angular aperture. The most perfect attainable objective then would be that which concentrates the greatest attainable amount of light within this area. To investigate the conditions which must be satisfied to this end we must determine the amount of light falling within a small circular area σ at P_0, the radius of which we will set as $a \operatorname{tg} \frac{1}{2}a$, where a is the angular aperture of the objective. It is evident that all the light of such refrangibilities as substituted in (1′) would yield values of P contained between $P_0 - a$ and $P_0 + a$ would fall within the area σ. These limiting refrangibilities shall be denoted by n_{-a} and n_{+a}. Only a portion of the light of refrangibilities less than n_{-a} and greater than n_{+a}, however, falls upon this area, the amount for light for the refrangibility n being clearly,

$$q_n \frac{a^2}{(P_0 - P_n)^2};$$

hence the total quantity of light falling upon σ would be equal to the sum of three integrals, the first taken from the extreme red up to n_{-a}, the second from n_{-a} up to n_{+a}, and the third from this last limit up to the extreme violet; that is, if q be this quantity,

$$q=a^2\int_{n_r}^{n-a}\frac{\iota_n}{(\mathrm{P}_0-\mathrm{P}_n)^2}dn+\int_{n-a}^{n+a}\iota_n dn+a^2\int_{n+a}^{n_r}\frac{\iota_n}{(\mathrm{P}_0-\mathrm{P}_n)^2}dn.$$

To find the value of n_0 which will render the last expression a maximum, it is necessary to find the first derivative of the function with respect to n_0 and set it equal to zero. Remembering that $\frac{d\mathrm{P}_0}{dn_0}=0$, we see that P_n, n_{-a} and n_{+a} are the only quantities dependent upon n_0, hence we obtain by differentiation under the signs of integration,

$$\frac{dq}{dn_0}=0=-2a^2\int_{n_r}^{n-a}\frac{\iota_n dn}{(\mathrm{P}_0-\mathrm{P}_n)^3}\frac{d\mathrm{P}_n}{dn_0}+a^2\frac{\iota_{n-a}}{(\mathrm{P}_0-\mathrm{P}_{n-a})^2}$$

$$+\iota_{n+a}-\iota_{n-a}-2a^2\int_{n+a}^{n_v}\frac{\iota_n dn}{(\mathrm{P}_0-\mathrm{P}_n)^3}\frac{d\mathrm{P}_n}{dn_0}-a^2\frac{\iota_{n+a}}{(\mathrm{P}-\mathrm{P}_{n+a})^2}.$$

But from the definition of the quantities n_{-a} and n_{+a} we have

$$(\mathrm{P}_0-\mathrm{P}_{n-a})^2=(\mathrm{P}_0-\mathrm{P}_{n+a})^2=a^2.$$

Hence the value of $\frac{dq}{dn_0}$ reduces to minus the product of $2a^2$ into the sum of two definite integrals, and the problem becomes simply the determination of the value of n_0 which will cause this sum to vanish, or, since $\frac{d\mathrm{P}_n}{dn_0}\frac{1}{(\mathrm{P}_0-\mathrm{P}_n)^3}$ must have opposite signs in the two integrals because $\frac{d\mathrm{P}_0}{dn_0}=0$, that value which will make the two integrals equal. If both ι_n and P_n were symmetrical with respect to some one value of n, that value would evidently answer the condition; otherwise it is necessary to know the function ι_n.

It would be easy to find a transcendental function which would express empirically the photometric observations of Fraunhofer, or the more recent and elaborate ones of Vierordt, but a simple consideration of the physical limitations of the problem will enable us to dispense with this operation.

Hitherto we have made no restrictions as to the value of σ. Let us now suppose that σ is so small that it may be regarded as the image of a star, then a is small and, since $\frac{d\mathrm{P}_0}{dn_0}=0$, P_n may

be regarded as symmetrical with respect to n_0 for values not differing largely from P_0. Again, for white light, ϵ_n is shown by the photometric observations above named to have a single maximum corresponding to a certain value of n which we will designate as n_1, and consequently may be regarded as a symmetrical function of n in the region of this maximum. Finally $\frac{dP_n}{dn_0}$ is never large in practical cases between the limits n_r and n_p while $P_0 - P_n$ increases continuously in numerical value toward these limits. If then we set $n_0 = n_1$ the two definite integrals become sensibly equal and q is a maximum.

The value n_1 corresponds to light of a refrangibility greater than that of the Fraunhofer line D and less than that of E, nearer, however, to the former. The only prominent Fraunhofer line readily seen with a crown glass prism of moderate dimensions in this region is that of wave length 5614. This I will assume as defining n_0 and consequently the ratio of A to B in (3′).

In all substances practically useful in telescope-making, γ of (2′) is positive, therefore P_0 is a minimum.

The reasoning given above is evidently applicable to all forms of radiation transmitted by the lens system if appropriate definitions for q and ϵ are given and ϵ possesses a single maximal value. For instance, in the case of radiant energy, pure and simple, n_0 should equal n_r nearly (lenses of glass); and for a photographic objective where silver salts are to be acted upon n_0 should be nearly equal to n_G.

It will be observed that the term color and all considerations relating to color have been entirely omitted from the discussion. This is what we might have anticipated as a necessary feature from the remarks on page 170.

One consequence of the solution above developed may be here noted, viz: the focal plane is defined by P_0 and not by two like values of P_n greater than this minimum. This is contrary to the doctrine of some writers but in accordance with critical experiments.*

III. *Method of applying the results to the practical construction of an objective.*

The solution obtained cannot be directly applied as a guide in the construction of an objective, for P is by no means the simple function of n, A and B as implied in equation (1′) when real lenses are in question. Even if we confine our attention to central rays and employ the exact formulas of Gauss, the process becomes so involved that we would naturally seek an

* See paper cited above, pp. 434–435.

easier, even if indirect, method; to a still greater degree if we wish to consider the far more important marginal rays.

There are several evident methods of finding indirectly the constants of the objective, but the most practicable one has seemed to me the following:

We have as data α, β and γ in the formula

$$n' = \alpha + \beta n + \gamma n^2 ;$$

also F, the required focal length of the objective. Then set

$$\frac{1}{P_0} = \frac{1}{F} = (n_{5614} - 1)\ A + (n'_{5614} - 1)\ B$$

$$A = -B\ (\beta + 2\gamma n_{5614}).$$

These last two equations yield the values of A and B. In the general equation (1′) substitute these values of A, B, α, β, γ with some known value of n other than n_{5614}, e. g., I have generally used the value n_C. Its solution will give the value of the focal length for light of the refrangibility C. Let this value of P be substituted in turn in equation (1′) and solve with respect to n. We shall thus obtain two values of n, one of which is n_C and the other a value greater than n_{5614} which we may call n_c, and if we substitute this in the equation connecting n and n' we shall be able to derive the corresponding value n'_c. This is all that the consideration of infinitely thin lenses can do for us, but from it we have found that the rays of refrangibility denoted by C and c should have a common focus, and we have also the values

n_c	n'_c
n_{5614}	n'_{5614}
n_C	n'_C

Having given, the thickness of the lenses and the distance between them, and having assumed radii proper to correct spherical aberration, we calculate the courses of three marginal rays of refrangibilities defined above, and of one central ray of refrangibility 5614. By successive trials and modifications of three of the radii we can meet the three conditions, that the marginal and central rays 5614 unite in a point on the axis, that this point is at a distance F from the second principal point of the system, and that the marginal rays C and c unite at another point on the axis. The remaining arbitrary constants, viz: the thicknesses, distance and fourth radius, may be utilized for the purpose of satisfying other conditions; but the consideration of such conditions is at present foreign to our purpose.

IV. *Practical tests of the value of the foregoing theory.*

There are two evident methods for determining the value of the results which we have obtained; one is to construct a telescope according to the principles developed in the theory and study its performance, and the other is to find how the practice of the most approved makers agrees with that as founded upon the theory. Both of these tests I have applied with thoroughness and will here give the results in the order named.

Three object glasses, involving the use of six varieties of glass, have been constructed according to the principles developed above. The first was of 4·1 inches aperture and 53 inches focal length, with the flint in advance of the crown. The materials of which this objective are made are the flint glass of Feil, No. 1237, and the crown glass of the same maker, No. 1219.* The focal length was purposely made small so as to yield the severer test.

The second objective has a clear aperture of $6\frac{1}{4}$ inches and a focal length of 91 inches. The crown lens is in advance and the curves are such as satisfy, for a first approximation, the conditions proposed by Sir John Herschel. This form, though ordinarily known as Herschel's, cannot be said to differ from that chosen by Fraunhofer at a date earlier than that of the publication of Herschel's paper.

The third experiment was tried at the instigation of my friend Mr. C. H. Rockwell, who bore the expense of the fine disks employed. These were ordered from Feil at Paris, and were of exceptional thickness in order to allow greater latitude in the selection of radii. The objective has a clear aperture of 9·4 inches and a focal length of 141 inches. It has undergone a critical investigation at the observatory of Cincinnati. As it possesses a number of novel features other than that of its color correction, I may give a complete description of it at another time.

All of these lenses were finished strictly in accordance with the theory developed in this paper, that is, the curves were ground very exactly according to the values yielded by calculation and the objective *finished* before testing. An extremely delicate spherometer was employed to determine the radii. As all the objectives are of the highest excellence, the usefulness of the theory may be regarded as demonstrated.

For the second test proposed, we possess the results of the studies of two distinguished spectroscopists on the character of the color correction of several large telescopes. To these I can add two more.

* The optical properties of these glasses as well as those of the $6\frac{1}{4}$ inch objective are given in a paper entitled, On the influence of Temperature on the Optical Constants of Glass. This Jour., vol. xv, pp. 269–275, 1878.

Professor Vogel, in the Monatsbericht d. k. Preuss. Akademie d. Wissenschaften for April, 1880, has described three large telescopes in respect to their color correction, one by Schröder of 298^{mm} aperture, another by Grubb of 207^{mm} aperture, and a third by Fraunhofer of 243^{mm} aperture, as determined by observing a stellar image spectroscopically. A fourth objective by Steinheil of 135^{mm}, less completely investigated, is of little importance to us here on account of its smaller size. The method was to determine the various lengths of the telescope when a stellar image, observed through the eye-piece armed with a prism, was caused to exhibit the greatest contractions at recorded intervals in its spectrum.

Professor Young, in this Journal for June, 1880, gives the results of his measurements on two telescopes by the Clarks, each of nearly nine and a half inches aperture. The method employed was analogous to that of Vogel except that a very powerful spectroscope was used and the limb of the sun taken instead of a star. By this means the focal planes for various wave lengths of light were determined by the position of the slit-plate of the spectroscope.

In the summer of 1879 I determined, by the method last described, the color characteristics of Mr. Edgecomb's telescope at Hartford, Conn., a 9·4 inch objective by the Clarks, and, with Professor Van Vleck's assistance, those of the 12-inch Clark at the Wesleyan University.

To compare these various successful practical solutions with that given by the theory embodied in this paper, I found by interpolation, using the first two terms of Cauchy's formula, the wave lengths corresponding to the various values of n_ω that is, those wave lengths which should have, according to theory, their focal point coincident with light defined by the Fraunhofer line C. They are for

	W. L.
Crown glass 1219	500·4
" " of 6¼ in.	499·5
" " of 9·4 in.	498·6
Flint glass 1237	500·7
" " of 6¼ in.	499·7
" " of 9·4 in.	498·9
Mean,	499·6

The corresponding values as derived by measurement from various telescopes are as follows:—

W. L.	Makers.	Authority.	Remarks.
530	Fraunhofer.	Vogel.	
465	Schröder.	"	
494	Grubb.	"	
490	Clark.	Young.	Princeton telescope.
522	"	"	Dartmouth.
495	"	Hastings.	Edgecomb's.
497	"	"	Wesleyan Univ.
499·0	Mean.		

The close agreement of these means may be taken as a decisive proof of the correctness of the theory.

The almost identical values of the wave length of light which should unite at the focus with the light C for six varieties of glass suggests another method of applying the results of the theory in practice, which is a very simple one. The nearest prominent Fraunhofer line to this wave length, that is, the nearest one which can be readily measured in a spectrum produced by a small crown glass prism, is W. L. 500·5. Hence, in practice, determine the indices of refraction for the lines C, W. L. 561·4 and W. L. 500·5 in both materials to be used; calculate the curves of the objective so that the spherical aberration for ray 561·4 shall vanish while marginal rays C and 500·5 have a common focal point. This method, though simple and direct, is without doubt sufficiently correct for all telescopes of moderate apertures and all varieties of glass hitherto used in their construction.

Johns Hopkins University, Jan., 1882.

Art. XV.—*To Cut a Millimeter Screw;* by Charles K. Wead.

The increasing attention paid to the metric system renders it more and more desirable to put the relations between this and the English system of weights and measures in as simple a light as possible. If a screw is to be cut on an ordinary lathe with its pitch a convenient number of teeth to the millimeter, centimeter or meter, the change-wheels are not adapted to the purpose. The only reference I have ever found to the subject is in Chambers' Encyclopedia, article "Wheelwork," where the problem is given to compute the gears needed to cut a screw of 200 threads to one meter, on a lathe whose feed-screw has four threads to the inch; by continued fractions the number of teeth, beginning with the spindle, is found to be 50, 48, 89, 73; i. e., if x=number of threads to 1 inch,

$x=\frac{50\times89}{48\times73}\times4=5{\cdot}08$, or, in 1 meter are $5{\cdot}08\times39{\cdot}37=200$ threads. This requires two gears with a prime number of teeth.

A simpler method than this I suggested four years ago to Messrs. Buff & Berger, of Boston, and by it they cut me some very satisfactory screws with 1 thread to the millimeter, using their new lathe with two dead centers; as it was new to them, and to all my friends familiar with mechanical work to whom I have spoken of it, I venture to publish it though it seems too simple to have escaped previous notice.

The method is based on the fact that 1 inch equals very nearly 25·4 millimeters: it would equal it exactly—

If one meter equals		**39·37008**	**inches.**
Clarke's value	**"**	**39·37043**	**"**
Kater's	**"**	**39·37079**	**"**

This "mechanical" meter differs from the best determination yet made, Clarke's, by no more than that differs from the next best one, viz: $\frac{1}{110\,000}$ part, though in the opposite direction. The form in which the direction was given to Buff & Berger was, "gear the lathe so as to cut a screw with twenty threads to the inch, with a gear of 100 teeth on the feed-screw; replace the 100 by 127 $\left(=\frac{254}{2}\right)$, and the pitch will be 1 millimeter, the theoretical error being much less than the mechanical error of cutting." Thus, on the lathe above referred to, $x=\frac{127}{20}\times4=25{\cdot}4$ to the inch, or 1 to the millimeter; again, $x=\frac{127}{100}\times4\div25{\cdot}4=\frac{1}{5}$—i. e. 1 thread to 5 millimeters.

On small lathes it may often be necessary to put the 127 gear on the arm because the screw and spindle are too near together, and perhaps to get a longer arm than usual; but neither this nor the calculation for any whole number of threads to the millimeter, centimeter, or decimeter will present any great difficulty to any one familiar with the principle.

Physical Laboratory, University of Michigan, Dec. 15, 1881.

Art. XVI.—*On the Gold-bearing Rocks of the Province of Minas Geraes, Brazil*; by Orville A. Derby.

The rock series of Minas Geraes, which have heretofore been recognized as auriferous, are the gneisses and mica schists of the crystalline group, and the quartzites, unctuous schists, and iron ores (itabirites), of the less highly metamorphosed group of rocks succeeding the crystalline series. To these may be added a second group of quartzites lying unconformably on the second metamorphic series. In all these rocks the gold is in, or in the immediate vicinity of, veins of quartz, generally if not always accompanied by pyrites, cutting the beds or accompanying the bedding, or in vein-like lines of a peculiar clay or iron ore. In a recent trip down the Rio das Velhas I noticed that long after having passed the region in which rocks generally recognized as auriferous were exposed on the river bank, the sand and gravel deposits of the bed are apparently as rich in gold as are those within that region. At the same time trial washings at the mouths of the rivers Parauna and Pardo, tributaries which at a short distance from the main river issue from the auriferous series about Diamantina, and might therefore be supposed to be richer in transported gold, proved that the sands of these streams are much poorer than those of the main river, and go to show that gold even in rapid flowing rivers is transported a much less distance than is generally imagined. An examination of the numerous quartz veins which traverse a series of inclined beds of clay slates, limestones and sandstones, quite distinct from the metamorphic series, revealed the fact that many of them carry pyrites and gold. This series has not, so far as I am aware, been recognized as auriferous. This series is of uncertain age, but is probably Paleozoic.

Another peculiar formation has been extensively worked at the city of Saõ Joaõ Delrei. The rock here is an ancient conglomerate containing rolled pebbles of itacolumite, unctuous schists, etc., and, except in its conglomerate character, bears so close a resemblance to the upper quartzite series above mentioned that it is difficult to doubt its identity. The gold is apparently in its secondary deposit in this rock. I have elsewhere attempted to show that at Grão Mogol, in the northern part of the province, a similar conglomerate of the same series is a secondary deposit of the diamond, and have now to add to this list of diamantiferous and, to a small extent, auriferous conglomerates, of the upper quartzite series, the heavy beds of Curralinho and Bom Successo to the east, and of Guinda and Sopa to the west of Diamantina. In the west of the province a newer conglomerate appears to have furnished the diamonds of the Jezuetaby and Abacté washings.

Art. XVII.—*The Flood of the Connecticut River Valley from the melting of the Quaternary Glacier;* by J. D. Dana. With Plate II.

[Continued from page 97.]

4. *Dimensions and velocity of the flooded Connecticut.*

In the preceding pages it has been shown that during the era of the melting of the glacier the Connecticut River and its tributaries participated together in the rising flood and in the work of transportation and deposition; that the tributaries brought in the chief part of the materials for the terrace-formation; and that the main stream left its best registerings of high-water mark in the deposits about or near their mouths. When the flood was at its height, the Connecticut was one continuous stream, hurrying seaward, as it is, though in a more moderate way, during a modern flood.

We may now seek to determine approximately the dimensions and velocity of the river when at maximum flood, taking up the several points in the following order:—(1) the height of the waters; (2) the mean depth; (3) the mean width; (4) the mean slope; (5) the velocity. As to the height along the valley, the facts are obtainable with a near approach to accuracy from the height of the normal upper terrace. But for the depth and width the data are less satisfactory: and for the slope and velocity, or the height of the water surface with reference to sea-level, on which slope and velocity depended, the evidence is still more uncertain.

1. Maximum height of the waters along the valley.—Before the flood had made much progress, the level of the river may have been the same with the present low-water level, or below it. And, between this condition and the end of the rise in the waters, there were successive levels along the valleys and some perhaps of long duration. There are no satisfactory means of determining the height either of the lowest or of any following stage, excepting the last—that of maximum flood.

With regard to the level of maximum flood we take the facts afforded by the heights of the normal upper terraces in the different parts of the valley. To show these heights at a glance and the continuous line of the water-surface I have plotted them for the several points of observation, together with the levels of low water and mean tide, so as to make a section of the flooded valley and stream; and this section is presented on Plate 2.

The plate contains, above the section, in figure 1, a map of

the river and its vicinity on a scale of 18 miles to the inch (or 1½ miles to the line), which extends from the village of Columbia, toward its source (about 28 miles from the more southern of its head lakes called Connecticut Lake) to Long Island Sound. The position of the western outliers of the White Mountains is seen to the east of Wells River and Haverhill. The Green Mountains, on the west, are too distant to be included. The section of the flooded stream just referred to is on the same scale as to length measured along the valley (not the river) but extends only to Stratford Hollow, 45 miles from Connecticut Lake, on account of the northeastward bend in the more northern part of the valley. The vertical scale of the section is 300 feet to the inch, or 25 feet to the line. In this section the longitudinal line AS indicates mean-tide level; BS the level above mean-tide of modern low water in the Connecticut, the figures under the line giving the same in feet for the places mentioned below; and CS′, flood-level when the flood was at or near its maximum-height. The figures directly below CS′ give the height of the surface above mean tide at each of the places stated, and those reading vertically, the difference between modern low-water level and the highest flood-level.

For the part of the section north of the Massachusetts line the levels for mean tide, low water, and maximum flood have been taken mostly from Mr. Upham's very valuable Report. But with regard to the particular terraces that mark the maximum height of the flood I diverge from him in many parts widely; and in a few other points I have depended on my own examinations. Some of these divergences I here mention in order that the nature of the changes introduced may be understood.*

The height of the "highest normal terrace" at Lancaster, according to Mr. Upham, is 30 feet above low water in the river. But the so-called "delta terrace" of Israel's Brook, just above the village, having a height of 75 feet according to his measurements (and my own), borders strictly the Connecticut River valley and was, beyond question, levelled off by the flooded river. It is the highest terrace at the place. Four miles north, at the mouth of Gaskill Brook, Mr. Upham's map has a terrace 100 feet above the river, which also borders the Connecticut valley; and 15 miles farther up the valley (3 miles above Stratford Hollow), there is a terrace 130 feet above low water. The actual height of flood-level at Lancaster and above was certainly up to the 75-foot terrace-plain, and probably up to the 100-foot, if not the still higher

* In the measurements of the heights of terraces I have used a hand-level. As the method is less exact than that employed by Mr. Upham, I have always in any remeasurements accepted Mr. Upham's results.

In speaking of a terrace, I often use the term *terrace-plain* for the plain that makes the top of the terrace, and *terrace-front*, for the front slope of the terrace, the angle of which is often 40° to 42°.

130-foot; it is made 100 feet on the chart; while the 130-foot level is indicated by a dotted line. Along the Fifteen-mile Falls, between John's River and the mouth of the Passumpsic, the region of the upper falls, according to Mr. Upham, is without regular terraces; but that of the lower, below Lower Waterford, has hills and terraces of stratified drift which reach in some places a level of 200 feet above the river. So great a height here favors the view that the 130-foot level at and above Lancaster is the most nearly right. My personal observations in the valley beyond Barnet were limited to the single locality of Lancaster.

At Barnet, in Vermont, three miles below the termination of the Fifteen-mile falls, the "highest normal terrace," according to Mr. Upham, is 148 to 166 feet above low water in the river. A large upper terrace west of the village off the mouth of Stevens' Brook, (a "delta terrace" of Mr. Upham,) I found to be 198 feet above the same level; and the small uppermost plain, 225 feet. It was manifest that these plains were not distinctively terraces of Stevens' Brook; for the brook now flows over stratified drift and between bluffs of it, 70 to 95 feet below the level of these plains; and it could not have worked at terrace-making at these high levels, except by the help of the Connecticut waters. That at least the lower of the two terraces above-mentioned was strictly a Connecticut River terrace is proved by the occurrence of it two miles north along the Connecticut valley (near the mouth of the Passumpsic) with a height of 198 feet according to Upham (p. 60) above the river at Barnet, or 190 above the river abreast of the terrace. The material of the Barnet terraces is mostly loam with fine sand in straticulate beds up to the 150-foot level; and at 164 feet, just north of the village, I found a clay-bed.

At Wells River, a "delta-terrace," 263 feet above low water in the river, was found to be the true normal upper terrace of the Connecticut instead of the terrace so-made by Mr. Upham having a height of only 123 feet.

At Haverhill the "highest normal terrace" of Mr. Upham has a height, as he states, of only 83 feet. But the true normal upper terrace is over three times this height, as is shown by the position and extent of the large Haverhill terrace-plain as well as the so-called "delta-terrace" of Oliverian Brook.

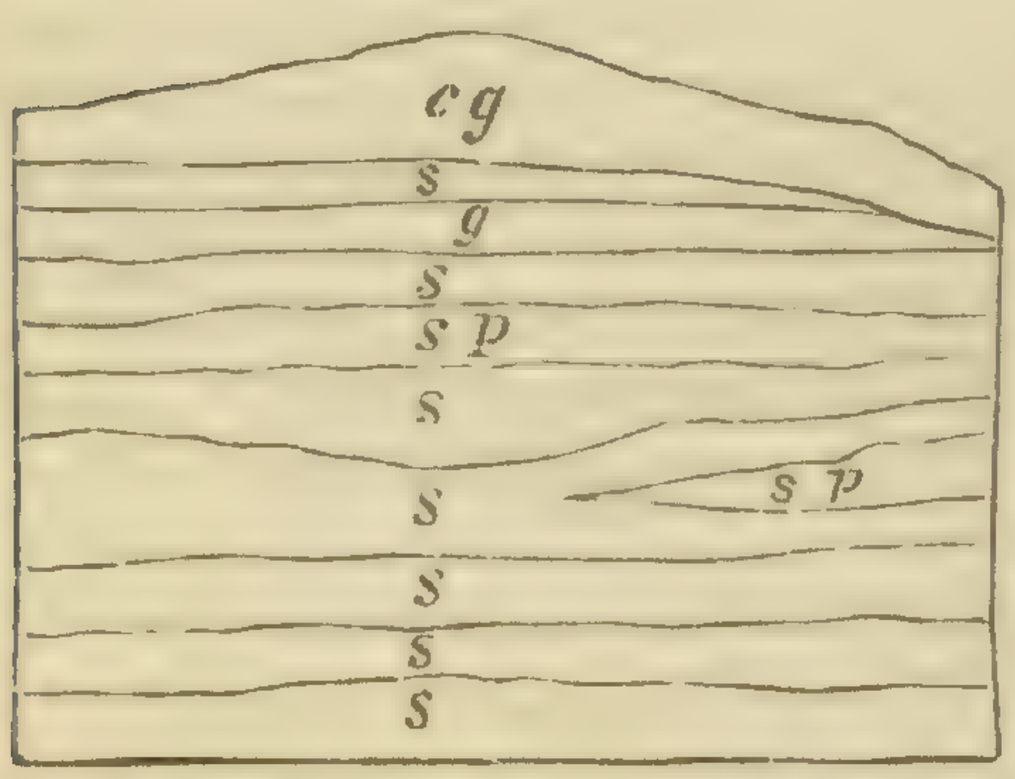
The terrace-plain on which the village of Haverhill is situated has great breadth, and continues along the Connecticut for two miles south of the village. Its height above low water in the river, by my measurement, up to a point in the street near the hotel, is 259 feet, and it rises eastward to 273 feet. Its surface consists of sand and sandy loam with some small pebbles, but becomes more stony toward the hills.

Mr. Upham alludes to the plain, but excludes it from the true terraces, stating that it is "a terrace-like area of *till*." He says that "at about one-fourth mile southwest from Haverhill village a gully recently made on a previously smooth slope, at a height

about 175 feet above the river and 75 feet below the village showed 15 feet of modified drift resting on till." What I found at the locality here (as I suppose) referred to, was a till-like deposit resting on the stratified drift. At the time of my visit in June last, there were three good sections of the terrace-formation along the road that leads north and west from the high village plain or terrace to the river-border plain, and in each the deposits were chiefly *finely-straticulate sand-beds.* In the *upper* of the three sections, exposing to view the higher 20 feet of the formation, the deposits were found to consist of sand and fine gravel, well bedded, and in part obliquely laminated.

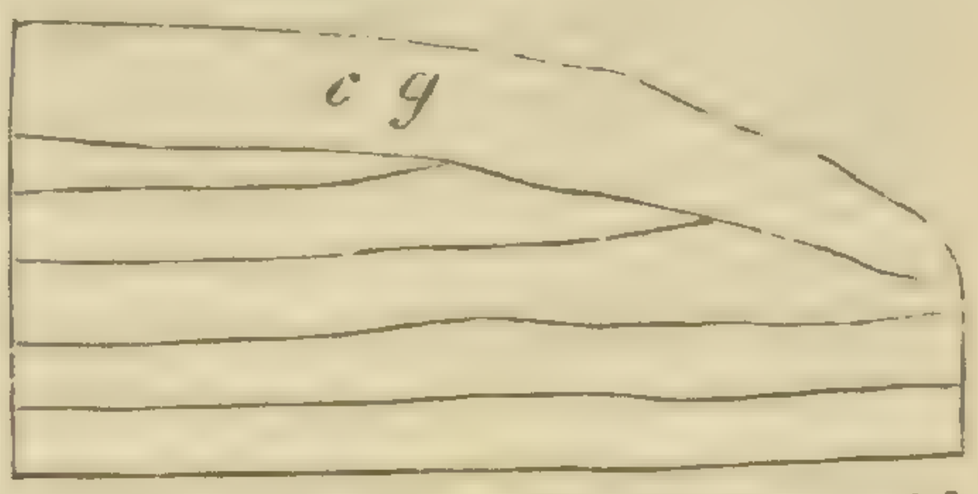
Lower down the road, 30 to 60 feet below the top of the plain, there was a *second* section, exposing about 30 feet in height of layers of finely straticulate sands, with some that were pebbly. This stratified drift had a capping of cobblestone material which lay somewhat unconformably over the beds. The character of the section is shown in figure 1; the sand beds are lettered *s* in place of being dotted or lined, because the very delicate straticulation would be misrepresented in any engraving unless the figure were made inconveniently large. The cobblestone capping, *c g*, cuts obliquely the upper of the stratified beds.

1.



Layers of finely straticulate sand (*s*) and sand and fine pebbles (*s p*) overlaid by coarse gravel, till-like (*c g*).

2.



Section 3. Layers of sand, with some of fine gravel, finely bedded, overlaid by a till-like deposit (*c g*).

The *third* section, a few rods farther down the road, carries the section of the terrace-formation down from 65 to 90 feet from the top, or more than half of the way to the 83-foot terrace; and this was probably the position of the gully mentioned by Mr. Upham as situated about 75 feet below the village. Its beds were like those of the preceding section. The capping of stones and earth, seen in the former section, was continued here, and had greater thickness with larger unconformability to the stratified beds beneath; and some of its stones were angular and two feet in diameter. Figure 2, representing the upper half of this exposure, shows the position of this stony deposit, *c g*, in relation to the beds beneath.

This till-like deposit is thus a superficial mass lapping down the slope, quite independent of the terrace-formation; and it is there-

fore of subsequent origin. It was probably dropped by floating ice. The Oliverian Brook, which here enters the Connecticut, comes directly from the southwestern part of the White Mountains, —Mt. Moosilauke, 4811 feet high and not a dozen miles off, being its source (see map), and other peaks, 2000 to 2500 feet in height, bordering its course.* The section at the time of Mr. Upham's examination of it must have shown the till-like deposit but not the beds beneath.

On an ascent of the terrace half a mile farther south I found evidence of sand-beds and fine gravel, but saw nothing of the till-like capping; and it was evident that the latter was a local deposit. Neither did I observe evidence of it near the village over the top of the plain.

At Piermont, the "delta terrace" of Eastman's Brook, 258 feet above low water level, is so situated evidently with reference to the Connecticut valley that it should be taken as the normal upper terrace, instead of the 78-foot terrace made the "highest normal" by Mr. Upham; and at Fairlee, a "delta terrace" of Jacob's Brook, having a height of 247 feet, is the upper terrace, instead of a 57-foot terrace so made by Mr. Upham.

In the north part of Norwich, the kame, according to Mr. Upham, has a height of 189 to 224 feet above low water in the river; and the mean of these extremes, 207 feet, is not too high for flood level, and this is taken as the height instead of the 159-foot terrace of Mr. Upham.

In Hanover, the Mink Brook "delta terrace" carries the height up to 207 feet above low water in the river.

Between Hanover and White River Junction—four miles apart —there are, near midway, falls of 40 feet.

At White River Junction, the southwest kame warrants carrying the level up to 213 feet at least, in place of 177; and a terrace to the west of it makes the full height, as I found, 242 feet. The correctness of this higher level is sustained by the height which Mr. Upham gives on his map for the upper terrace and kame three miles south, in North Hartland, namely, 242 feet, and nearly by that of the "delta terrace" of Lull's Brook, 227 feet high, four miles farther south in Hartland.

In Windsor, I made measurements up to the high plain west of the village, and found it 216 feet above low water in the river, which is the height taken in place of the 196-foot terrace. The material of the terrace was fine sand and loam, but slightly pebbly in the upper portion. It is a terrace of Mill Brook, but not less so of the Connecticut.

These examples are sufficient to explain the course I have pursued.

For the height of flood-level in the part of the valley passing through the State of Massachusetts I have used some of the

* Professor C. H. Hitchcock observes, in vol. i of the Geological Report of New Hampshire (p. 217), that the Oliverian Brook in Haverhill may be expected to show signs, through boulder deposits, "of a local glacier descending the west flank of Moosilauke."

measurements of Professor Edward Hitchcock, and for the Springfield region, the survey of the Springfield City Engineer, as in a former paper.* I have personally made levelings in Holyoke, Willimansett, and South Hadley. It was my purpose to have made further observations in the State, but finding that Professor B. K. Emerson, of Amherst College, was engaged in a thorough study and mapping of the terraces, I gladly left the subject in his hands.

The height of the very extensive upper terrace of western Northfield, the town adjoining New Hampshire, I have taken from Mr. Upham, his map covering this Northern Massachusetts town; he gives it at 198 to 213 feet above low water in the river. Although the terrace borders most obviously the Connecticut valley, he speaks of it as a tributary's terrace, and takes for the "highest normal terrace" one only 128 feet high above the river. The true upper terrace extends to Gill; and a corresponding one on the eastern side of the Connecticut, but little lower, continues with small interruptions all the way to Miller's Falls.

For the height of low water level in the Connecticut Valley, between Holyoke, in Massachusetts, and Hartford, Connecticut, I have used the section made in connection with the very exact survey of General Ellis, making part of the Report† of General Warren for the year 1878. The height for the river above Holyoke has not yet been accurately determined. In the section, the height at the top of Turner's Falls is made 180 feet, and at the foot of the rapids, 120 feet.

In the Connecticut part of the section, the heights are, with one exception, from my own levelings. My former measurements have been repeated, in order to be able to refer the heights to mean-tide level, and others have been made.

The extensive terrace east of the Connecticut, which commences 8 miles north of Springfield and has a width in Massachusetts of 2 to 6 miles, with an average height of 180 feet above mean tide, extends as many miles into Connecticut, and east of Thomsonville spreads eastward half a mile beyond Hazardville, or 4½ miles, with a height of about 160 feet. It is in general a plain of unfertile sands, but fine-pebbly on some higher portions. It seldom rises to the level of maximum flood. Just south of Thomsonville, this upper plain appears about the isolated Enfield ridge, at a height of 214 feet. Two miles west of the Connecticut, nearly opposite the latter place, it has full height, 215 feet, about the isolated ridge of Suffield village. The material is coarse gravel. A northern portion of the Suffield ridge is 10 feet higher and is of coarse cobblestone material, and may be till.

Northwest of Hartford, the upper terrace is well defined half

* Southern New England during the melting of the Great Glacier, this Journal III, x and xi, 1875, 1876.

† Annual Report of the Chief of Engineers for 1878, Appendix B 14. Report of the surveys and examinations of the Connecticut River between Hartford, Conn., and Holyoke, Mass., made since 1867, by Brevet-Major General G. K. Warren, Major of Engineers, U. S. Army.

a mile from the gap through the trap for the Farmington River, and has a height, by aneroid, of 210 to 215 feet. The plain in the vicinity of the Manchester depot, on the east of Hartford, is about 200 feet in height.

South of Hartford, east of the Connecticut, in Glastenbury, a broad terrace rises abruptly from the river and spreads two to three miles eastward, with a height of 170 to 190 feet. Two miles north of Middletown it is reduced to a broad shelf against the eastern hills, a mile or more from the river, and has a height of 186 feet above mean tide east of Gildersleeve's landing.

At Middletown, where the river turns eastward to pass the Narrows, the waters spread 2 to 4 miles west of the Connecticut. At Rock Falls, and just beyond, the terrace deposits have a height of 193 to 199 feet above mean-tide; and at Pine Grove Cemetery the wide plain is, according to an aneroid measurement by Professor Wm. North Rice, of Middletown, 199 feet.

The facts make the maximum height at Middletown probably between 193 and 199 feet.

Nearly two miles southwest of Middletown, just east of the Haddam road, stratified sand and gravel make the upper part of a hill which is 235 feet high above mean tide. If a part of the terrace-formation, it would make the maximum level of the flood and of the Middletown dam 40 feet above the height just mentioned. But it has a capping 3 to 4 feet thick of coarse unstratified material containing some scratched stones, and is probably of earlier origin. The hill stands between higher, rounded, till-covered hills on the west and east, with low, marshy land adjoining, and between a wide region of lower land to the south (the Johnson Lane district), and the valley of the Connecticut to the north and northeast; and if waters were above 200 feet over the region, they would there flow across to the Connecticut. The conditions of origin are not easily explained.

The height of the line of flood-level in the section on Plate 2 is in several cases below that which the highest terrace-plain seems to authorize. Thus, at Haverhill, the upper terrace-plain has for its highest part to the eastward 673 feet, 10 feet above the height in the section; at Brattleboro, where 410 feet is taken for the height of flood-level, a terrace occurs according to Upham's map, of 425 feet; at Dummerston, 5 or 6 miles north, there is one either side of the stream of 420 to 440 feet; in Northfield the terrace rises toward the hills 15 feet above the level taken for the upper level; and so in several other cases. It is quite common for a terrace-plain to rise in level above the average height as it nears the hills: and as this may come in part from material carried down the slopes at the time of the flood and washed over the surface raising it above true flood-level, I have not generally taken the extreme height thus afforded. Moreover the terraces of tributaries often rise rather rapidly where within a confined valley, owing to the great amount of transported material. I have sought to be rather under the true height than above it in

all judgments. It is quite possible, however, that a more exact study of the terraces will place the flood-level higher than I have done; certainly higher, I think, rather than lower.

The section gives an impressive idea of the greatness of the ancient flood. The river had, as it shows, two great falls in its course, one, the Fifteen-mile Falls to the north, below Lancaster, the other a twenty-five mile fall on the way to the Sound from Middletown, Connecticut. It took its full magnitude west of the White Mountain region, after its junction with the Passumpsic, one of its two chief sources, and after accessions from its other head waters, Stevens' Brook and Wells River on the west, and the Ammonoosuc River and Oliverian Brook on the east. At North Haverhill the height of the water above modern low-water level was at least 250 feet, and its width exceeded two miles; and it was nearly or quite 200 feet above the same level at Middletown in Connecticut, 172 miles south of Haverhill and 26 miles in a direct line along the valley, from the Sound. The diminution in depth southward was evidently a consequence of the increasing width, especially after entering Massachusetts.

The Fifteen-mile falls were long rapids over a nearly continuous slope of coarse till, showing abundant bowlders but with scarcely any exposures of solid ledges.* The falls below Middletown began in a plunge over a dam 190 feet high above modern low water, that was formed at the Narrows—a cut, but 650 feet wide in its lower part, through a high rocky ridge of crystalline schists and enormous granite veins. Below the dam the descent in the waters is registered in the terraces of the valley (see section on Plate 2); and it is shown thereby to have been gradual and not a vertical plunge. The dam was probably an ice-dam as explained in a former paper.† Above the dam the waters spread westward over the Middletown region to a distance from two to four miles, covering the tops of some prominent hills. Yet those of the hills that are within one to two miles of the river are mostly free from stratified drift and terraces, and have instead rounded surfaces and a deep covering of till: and it may be that this scoured condition was produced by the violent rush of the waters at the final destruction of the ice-dam.

To enable the reader to compare the ancient with the modern floods of the Connecticut, a section of the latter from Holyoke to Long Island Sound is given on the general section. For the part from Holyoke to Hartford it is taken from the section published in General Warren's Report as the result of a series of careful measurements by General Ellis. For the

* Report of Mr. Upham, p. 24. † This Journal, III. xi. 178, 1876.

height at Middletown I have taken the height of the highest modern floods at that place, $25\frac{3}{4}$ feet. These high floods of modern times are largely dependent for their height on obstruction by ice at the Narrows, like those of more ancient time.

The comparison which may thus be made can give but a feeble idea of the actual contrast. The modern stream in its greatest floods retains still its tortuous course and abrupt bends, and the great width it takes in some parts is made by the spreading of only a thin layer of water over wide flood-grounds. But in the time of the great flood, the river for the most part rose above such obstacles, took the wide valley for its channel, and had an almost unimpeded course on its way to the ocean. In figure 4 on Plate 2, an enlarged map of the river-valley from Wells River to a point below Bellows Falls is given (from a map of the Atlas accompanying the New Hampshire Report). It shows by the dotted line either side, the east and west limits of the terraces, and thus indicates something of the extent to which modern bends were absent.

On the other hand the height of the flood as exhibited in the section is greatly exaggerated compared with the length—though hardly so if measured by the impression which the high terraces make on the mind of an observer. To aid the reader in eliminating this exaggeration, a section of a small portion of it with the natural pitch is given on the plate in fig. 3, below the general section of the river. This section represents the "Fifteen-mile Falls," along the twenty miles between the mouth of the Passumpsic and St. Johns River. According to Mr. Upham's Report, the whole fall in the 20 miles is 370 feet: the upper fall, 156 feet; the lower, 183 feet; and the descent between the two falls, 31 feet.

Some additional exaggeration is made apparent in the course of the following discussions.

From the facts presented in the section and others connected with the Connecticut valley and its terraces, we may obtain approximate results with regard to the *mean depth* of the flooded river, its *mean width*, the *mean slope* or pitch of the stream, and its mean *velocity*.

2. MEAN DEPTH.—In seeking to ascertain the mean depth of the flooded river at any place, we cannot rightly measure down to modern low-water level. For over the bottom of the valley, there is very commonly a wide terrace 60 to 80 feet above low-water; and, when the flood was far advanced, this terrace-plain may have extended across the narrow channel of the modern river and obliterated it. On account of the wide extent of this lower terrace, it appears to be necessary to deduct 60 to 80 feet from the whole height of the flood in most parts

of the valley; and for the sake of an estimate and not an over-estimate, 75 feet may be the amount deducted.

According to the section, the height above modern low-water level at Haverhill was about 260 feet; and this, diminished by 75, gives for the depth 185 feet. So we obtain for Hanover and White River Junction, if the height of the intervening falls be divided between them, 225–75=150 feet; for Windsor, 216–75=141 feet; for Brattleboro, 210–75=135 feet; for South Vernon, near the border of Massachusetts, 207–75=132 feet.

We may thence take for the average depth north of the Massachusetts line, 140 feet. The depth on the southern boundary of Massachusetts obtained by the same method would be 125 feet, and at Hartford in Connecticut, 125 feet. But the width is so much greater after entering Massachusetts, that it is quite certain, as already stated, that the less depth is more than balanced by the greater width.

3. Mean width.—In order to obtain an approximation as to the mean width of the flooded stream between Wells River and the Massachusetts line, we may review, for a few localities, not only the width (which I take from Mr. Upham's map), but also the areas of cross-sections.

At Haverhill, the highest normal terrace of the east side rises nearly to its full height, 263 feet above low water level, directly from the lower terrace-plain of 83 feet. The width of the channel-way on the map, above the 83-foot terrace, is 4,000 feet. Taking for the depth of water 263−83=180 feet, the area of the cross section, with this width, would be 720,000 square feet.

Between northern Orford and Fairlee, 8 miles south of Haverhill, the higher terraces are wanting. Taking for the width only that covered by the valley deposits, that is, the low terraces—it is about 3,300 feet—which is too low, because there is no high terrace to mark the actual width, and the low terraces referred to are only 55 feet above low water. The height of the flood as given in the section, Plate 2, is 252 feet; thence, with the depth (252−55=) 197 feet, and with 3,300 feet as the width, the area of cross-section is 650,000 square feet.

Where the valley passes Norwich and Hanover, the most prominent terrace has a height of about 150 feet above low water in the river, while the upper one, marking flood limit, is 210 feet. The channel-way has hence a narrow *lower*, and a wide *upper* section. For the width of the former, I have measurements obtained for me by Prof. R. Fletcher, of the School of Civil Engineering at Dartmouth College. The measurements were taken between points half-way up the steep terrace-front.

600	feet	below	the bridge	crossing	the river, width 1,980 feet.
400	feet	above	"	"	" 1,350 "
800	"	"	"	"	" 1,270 "
2,500	"	"	"	"	" 1,000 "

The mean of the above numbers is 1,400 feet. At the last of the localities, the river has on its west side high rocks and therefore no terraces, and the bottom terrace is only 30 feet above low-water level. This number should, therefore, be thrown out, the small width having probably been compensated for by increased velocity. In this case the estimated mean width would be over 1,500 feet.

For the width of the upper section of the flooded stream, or that above the level of the 150-foot terrace, we have the interval between the highest terraces of the two sides of the valley in the line of the villages of Hanover and Norwich. 8,000 feet; and on a transverse line 2,500 feet below the bridge (see above), 4,000 feet. The mean between the two is 6,000 feet. To obtain the area of a cross section we have then 1,500 feet for the mean width of the lower section of the flooded stream, and 6,000 for the upper. For the depth of the lower section, we deduct from 150, 47 feet, this being the height above low water of the higher of the bottom terraces, and obtain 103 feet; and for that of the upper, 210−150=60 feet. The area of the whole cross-section, afforded by these numbers, is 514,500 square feet. The falls of 40 feet in the river, two miles below Hanover, suggest a good reason for the little height of the lower terraces.

Above Brattleboro, the mean width, as nearly as we can obtain it from Mr. Upham's map, is 5,000 feet. The depth, deducting 75 feet for the lower terrace, is 135 feet; and this gives for area of cross section, 675,000 square feet. At the narrowest part 3 miles north of Brattleboro, the width of the channel-way is 3,500 feet; but this is so only for a short distance, and the lower terraces here have a height of but 35 to 50 feet. With this width and deducting only the mean between 35 and 50, or 43 feet, for the lower terrace, the area of section is about 585,000 square feet.

From these results, although not based on accurate measurements, we may conclude that the area of cross-section for the Connecticut, between Wells River and the Massachusetts line, averaged *at least* 560,000 square feet, and hence that the mean width, if 140 feet be taken as the mean depth, was probably not less than 4,000 feet.

4. Mean Slope.—We may *first* deduce the slope or pitch on the assumption that the land and ocean had their present relations as to level; and then, *secondly*, consider the evidence as to these relations having been different from now, and *finally* make other calculations in accordance with the conclusion reached.

A. *Mean slope of the river in case the land and ocean had their present relations as to level.*—Supposing the land and ocean in the era of the flood—the early part of the Champlain period—to have had their present relative level, the slope of the stream may be taken directly from the section on Plate 2, the figures along the upper line giving the height at different localities along the valley, and those by the lower lines the distances as *measured along the valley* (taking no note of the turns in the river) between localities, on a scale of a twelfth of an inch to 1½ miles. We thus find for the slope:

	Distances in miles.	Slope per mile.
Haverhill (655 ft. flood-level) to Windsor (520),	41	3·3 feet.
Windsor (520) to South Vernon, Vt. (396),	49	2·5
South Vernon (396) to Springfield, Mass. (240),	44	3·5
Springfield (240) to the Middletown Narrows (195),	38	1·2
Narrows (195) to Long Island Sound,	26	7·4
Haverhill (655) to the Middletown Narrows (195),	172	2·7
South Vernon (396) to the Middletown Narrows (195),	82	2·5
Haverhill to the Sound,	198	3·3
South Vernon to the Sound,	108	3·6

From the above it appears that, except for the dam at the Middletown Narrows, the mean slope from Haverhill to the Sound would have been 3·3 feet per mile, or the same as from Haverhill to Windsor. But, owing to the dam, the mean slope to Middletown is but 2·7 feet, while below the Narrows it is 7·4 feet per mile.

B. *Mean velocity.*—To obtain the velocity, we have the data above deduced for the mean width, depth and slope of the flooded river.

Another element required is the amount of resistance from bends and obstructions in the stream. It is fortunate for the calculations that the Connecticut valley follows a remarkably straight north-and-south course. With the water raised 200 feet and more above modern low water and a width thereby averaging nearly a mile along the course north of Massachusetts and more than this south, the bends are only those of very large curvature, which would not affect greatly the velocity of a rapid stream. On the map of the river and valley between Wells River and Bellows Falls, figure 4, Plate 2, the band covered by the deposits, indicated by the dotted outline, shows that the waters made *nearly a straight stream*. The map is somewhat short of the truth, since the upper terraces are absent in parts of the valley and particularly so for the narrower part along from Ely to Piermont. Only a map that gave on each side of the valley the contour-line corresponding to the height of maximum flood, and also the limits of the channel-way as marked by the inner limits of the highest terraces, would show fully the degree of straightness.

Below Windsor there is a prominent obstruction in Mount Barber, an elevation in the direct course of the stream and a mile wide; but there was abundant room for the river on either side of it. Another obstructing mass of ledges probably existed just south of Turner's Falls southwest of the mouth of Miller's River, in Massachusetts, ten miles south of South Vernon, where the Connecticut river makes a westward bend of six miles to Greenfield. This *probably existing* "mass of ledges," is now beneath the terrace formation, the top of which is the elevated plain between Montague City and Miller's river; and its existence at no great depth beneath the plain is inferred from the terrace deposits—on the ground that these are an indication of slackened flow in the waters. The flooded river passed both along the east and west sides of these obstructing ledges, as well as over them at highest water. After passing this place, the river at highest flood had an open and almost straight way to Middletown, which was nowhere less than 4,000 feet in width, though narrowed at Mt. Holyoke, Enfield Falls and Glastenbury.

Whenever a careful topographic survey of the Connecticut valley shall have been made, which shall lay down throughout it contour-lines corresponding to the maximum flood-level, it may be possible to arrive very nearly at the amount of resistance produced by the flexures. At present it is not possible to reach any accurate estimate: and the best that we can do is to use a diminished width for the basis of the calculations and make a further allowance by estimate. The results with regard to the velocity are hence obtained below for the river with a breadth of 2,500 feet, as well as with that of 4,000 feet.

The formula for the calculation of the velocity here employed is that given by Humphreys & Abbot for large rivers in their admirable Report on the Mississippi River, numbered 41, on page 312. It is applicable strictly to a limited portion of a large river without bends. It is as follows:

$$v = ([225r, s^{\frac{1}{2}}]^{\frac{1}{4}} - 0{\cdot}0388)^2$$

in which v is the velocity sought; s, the sine of the slope; and r, the mean radius = area of cross-section, a, divided by $p+W$, or the length of the wetted perimeter (p) *plus* the width at surface. In the general formula, the sine of the slope $= s = \frac{h'}{l}$.

l = length of limited portion of the river. $h = h_{,} + h_{,,}$ = difference of level of the water-surface at the two extremities of the distance l, in which $h_{,}$ = the part of h consumed in overcoming the resistances of the channel supposed to be straight and of nearly uniform cross-section, and $h_{,,}$ = the part of h consumed in overcoming the resistances of bends and important irregular-

ities of cross-section. In the equation for large rivers, above quoted, $h_{,,}$ is thrown out by the conditions.

The following are the results for the portions of the river indicated in the column to the left. The slope is given in feet per mile. The velocity is stated in miles per hour and in feet per second, and both for a width of 4,000 and 2,500 feet.

		Velocity, width 4000 feet.		Width 2500 feet.	
	Slope.	In m. per hour.	In ft. per second.	In m. per hour.	In ft. per second.
Haverhill to Windsor	3·3	13·07	19·16	12·93	18·97
Windsor to South Vernon	2·5	12·18	17·87	12·06	17·69
South Vernon to Springfield	3·5	13·26	19·45	13·13	19·25
Springfield to Middletown dam	1·25	10·23	15·00	10·12	14·85
Haverhill to Middletown dam	2·7	12·42	18·22	12·30	18·03
South Vernon to Middletown dam	2·5	12·18	17·87	12·06	17·69
Middletown dam to the Sound	7·4	16·02	23·49	15·85	23·25

From the above, the mean velocity for the whole river from Haverhill to Middletown, would have been, assuming that the relations of the land to the sea-level were the same as now, over 12 miles an hour, even supposing the mean width to have been but 2,500 feet.

This great velocity, or even one of 10 miles an hour, is not compatible with the character of the deposits which lie at different levels beneath the surface of the stream—both those at 140 feet below the surface and those at higher levels. The former, away from the region of the mouths of tributaries, consist almost uniformly of nearly incoherent but stratified sand, or sandy loam, and in some parts of clay; and similar fine materials in general constitute the terrace-deposits of the higher terraces (including the terrace-fronts) up to a level within 50 feet of the highest flood level and often nearly to the uppermost plane.*

According to trials, a current of *one-third of a mile* per hour will take up and transport fine earth or clay having the particles ·016 inch in diameter; and one of *two-thirds*, fine sand, the mean diameter about ·064 inch. Accordingly, since the mean diameter of the largest transportable particles varies as

* Darcy and Bazin, in their *Recherches Hydrauliques*, give the following as the bottom velocity (in feet per second) at which scour commences for the different materials mentioned, and the corresponding calculated mean velocity.

	Bottom velocity.	Mean velocity.
1. Earth	0·26	0·33
2. Loam	0·50	0·65
3. Sand	1·00	1·30
4. Gravel	2·00	2·62
5. Pebbles	3·40	4·46
6. Broken stone	4·00	5·15
7, Chalk	5·00	6·56
8. Hard rock	10·00	13·12

—Cited from the Encyl. Brit., vol. xii (1881), Art. Hydromechanics.

the square of the velocity (supposing them of like density) a stream of 2 miles an hour at bottom would carry along stones of about 0·6 inch in diameter; and one of 4 miles, stones $2\frac{1}{3}$ inches in diameter. The mean velocity is generally about a third to a sixth greater than the bottom rate, the differences diminishing as the velocity increases. If the mean velocity were 10 miles an hour, that of the bottom would be over 8 miles (unless greatly impeded by transported material)—rapid enough to scour down to stones and solid rock.

This argument is not based on the depositions made by the stream; for these were more or less made over the flood-grounds of the river as the waters rose; and the waters over flood-grounds, even in the case of rapid streams, are variously impeded by the amount of transported material, friction in the shallow waters, and obstructions, often dam-like, due to the uneven surface beneath; but on the transporting force of the stream at the time of maximum flood, when all the terrace-plains except the very highest were swept by the flowing waters. It may be questioned whether the lower terrace of 60 to 80 feet above present low water, which is almost everywhere —if the mouth of no tributary is near—made of sand or loam where not of clay, was actually the bottom of the flooded stream; whether, the waters did not excavate down to stones and rock, so that this terrace is of subsequent formation. But this supposition does not rid the subject of the fact that the flooded stream did not take up and carry off the sands of its bottom. For the range of higher terraces usually 140 to 160 feet above low water in the river, were at the time under 50 feet in depth of water; and these, away from tributaries, usually consist at top and below of fine sand or loam, or of fine gravel. The great terrace-plain north of White River Junction was one of this kind with 50 feet of water above it; and it consists at surface mostly of fine sand or sandy loam, with some portions of fine gravel; and, below the surface, except near the river, chiefly of sand with some clay. The materials of the corresponding terrace near Windsor are still finer. The high terrace-plain east of Greenfield and south of Turner's Falls, between Montague City and Miller's Falls, called the Montague City plain, lies directly in the way of the Connecticut, as stated on page 191; and although flowed over at the highest flood by water 10 to 30 feet in depth, it consists chiefly of fine sand, or loamy sand, with some clay, except on its eastern and north-eastern side, where it received contributions from the violently torrential Miller's River.

Thus all parts of the valley bear like testimony to a velocity in the waters at maximum flood which was not great enough to carry off fine gravel, and this means a velocity not exceeding

two miles an hour at bottom: which is the condition in a stream having a mean velocity of 3 to 4 miles.

The transported materials in the waters would have had a retarding effect: but small, since as already shown, they were only sand and finer material, and the fine straticulation indicates a free-flowing stream (p. 93). The deduced mean velocity, over 12 miles an hour, could hardly have been reduced by all the causes of retardation together to less than 9 or 10 miles an hour.

We are thus led to enquire what range of evidence there may be as to the existence of a less pitch in the valley, to cause the less velocity, or as to any other method by which a diminished velocity might have been produced.

One method is by means of *dams;* a second, by *changed relations between the level of the land and sea.*

B. *Dams on the Connecticut Valley as a possible source of less slope in the waters.*—That it may be understood what is to be explained by means of dams, or in other ways, we here review the facts with regard to the clay-deposits and associated sand-deposits of the valley.

It is to be remembered that the sand-beds and those of finer material ordinarily make not only the lower terraces but also the highest, where tributaries are absent, to within 50 and often 20 or 30 feet of their tops; and that this is so even high up the Connecticut, as at Barnet, not two miles south of the junction with the Passumpsic, where these finer deposits extended to a level of 150 to 200 feet above low water in the river.

Clay-deposits are widely distributed about Hartford to a height of 75 feet and less above tide level, or low water in the river. At Springfield, 58 miles in a direct line from the Sound, they are of great extent at a height of 170 feet above the sea level: at Holyoke, 8 miles north, on the west of the Connecticut, and at Willimansett, nearly opposite, on the east side, at 175 feet; on the eastern slope of Mt. Tom, south of Northampton, according to Professor E. Hitchcock, at 178 feet: and over the Amherst region, as I learn from Professor Emmons, of Amherst, at nearly the same level. The dam below Middletown suggests a possible explanation of the origin of quiet water for the making of the clay beds about Hartford: for if the dam were but little more than a third of its final height it would be sufficient; and if raised to within 10 feet of its full height, it might have produced the quiet movement in the waters required for all the clay-beds up to and including those of the Amherst region. That the height of the dam was actually so near its extreme height, when the terrace deposits

of Springfield were 50 feet and more below their maximum height, is far from certain. The Springfield, Willimansett and Amherst deposits are situated close by the present river channel, and hence seem to be safe evidence as to the very small velocity of the river, which they might not be if they were more distant flood-ground deposits.

Clay-beds exist just *below* the Middletown dam, on the eastern or Portland side, to a height of 75 feet above modern low water, in a very steep and short valley. The place would seem to be very unfavorable for such fine depositions if the dam were then formed, and especially if at its final height. But it is possible that the ice had made a barrier to the little stream, so that the evidence from these clay-beds is not conclusive against the existence of the dam during their formation.

But, further, extensive clay-beds exist in the high and broad terrace of Montague City, east of Greenfield, 300 feet above tide level. Again, on the terrace-plain, between Windsor and Hartland, 500 feet above the sea-level, or 190 feet above the river, clay comes to the surface in a field so as to be turned up (as I observed) by a plough, the material along the plain elsewhere being fine sandy loam. South of this, in Windsor, the deposits are fine loam and sandy loam to a height of 500 feet, with clay nearly to this height. North of White River Junction clay was exposed near the river at a height of 460 feet above mean tide, or nearly 130 feet above the river at low water. In Hanover, N. H., the clay-beds extend along for 3 or 4 miles or more; and in the village they reach a height of 523 feet above mean tide, or 150 feet above the river—clay having been taken out at this level in excavating for the cellar of Professor Hubbard's house (as he informs me), opposite the northwest corner of the College Square; and on the opposite side of the Connecticut, in Norwich, there are clay beds at corresponding heights up to 500 feet. Just north of the village of Barnet a clay-bed comes to the surface in the terrace-plain near the river at a height of 610 feet above mean tide and 158 above the river. These few examples will no doubt be multiplied greatly by careful exploration.

For making the clay-beds north of Amherst, the Middletown dam would have been of no avail; and besides this dam there is no satisfactory evidence of any other. This is shown by the regularity in the pitch of the terraces along the valley. The valley is comparatively narrow between Mt. Holyoke and Mt. Tom; but the heights of the terraces give no evidence of a dam, and the clay-deposits are at nearly the same high level above and below. Another narrow way for the modern river is between Mt. Toby and Sugar-Loaf, a dozen miles north of Mt. Holyoke: but here the waters of the flooded river

had a passage east of Mt. Toby, and a very wide one west of Sugar-Loaf. There are like objections to the location of dams at other places. Mr. Upham says, on this point, especially with reference to the part of the valley north of Massachusetts, that the idea of dams along the valley is not sustained by the topography of the valley or the distribution of its terraces.

As dams have, therefore, not existed where they would have been needed to reduce the slope of the stream and make a velocity that would admit of extensive depositions of sand through all the valley and of clay-beds in many parts to various heights up to 610 feet above the sea-level, we may consider what effect may have come from changed conditions in the level of the land and sea.

C. *Slope and velocity under changed relations in the level of the land and sea.*

a. *Evidence of a change afforded by the heights of Elevated Sea-beaches.*—The fact of a wide difference between the flood era and modern time along the coast region is put beyond question by the heights above existing tide-level of shell-bearing beach-deposits.

The facts are well known. The more important are here tabulated:*

	Latitude.	Height.
New Haven or New London, on the Sound.	41° 14′	15 to 25
Sankaty Head, Nantucket,	41° 17′	45
Point Shirley, near Boston.	42° 19′	75 to 100
Lewiston, Maine,	44 6′	200
Mt. Desert, Maine,	44° 20′	217
Colchester, Vt., (4 m. N. of Burlington, on L. Champlain).	44° 33′	335
Middlebury, Vt.,	44° 10′	403
Montreal,	45° 31′	520
Les Éboulements, on St. Lawrence River,	47° 30′	about 600
Murray Bay, on St. Lawrence River.	47° 45′	

The facts prove (1) a difference of level compared with tide-level between the era of the beach-deposits and the present; and (2) an increasing amount of difference northward. They are all from the coast it is true, but from the coast of the northwest side of New England as well as from its eastern, southeastern and southern borders; and in view of their wide geographical range, and especially the fact, already made manifest, that the valley of the Connecticut must have had diminished pitch during the era of the flooded river, we may believe that the interior of New England experienced the changed re-

* The heights at Éboulements and Murray Bay, on the St. Lawrence, I have received from Dr. J. W. Dawson, of Montreal. The beds at Middlebury, Vermont, are of clay without marine shells; but, according to Professor C. H. Hitchcock, there is no higher land between them and Lake Champlain, and they could not have been made unless the waters of the lake were at the same level. The heights on Long Island Sound (north side) are based on stratified deposits along or near the Sound, but not shell-bearing. The shells in the Mt. Desert deposits indicate a considerable depth of water.

lations to the sea-level that we find indicated along the sea-coasts.

It being thus altogether probable that the *interior* of the country participated in the change, the amount of this change along any diameter would probably have had some relation to the amount at its extremities. As Montreal and Lake Champlain lie on the west side of the area, Murray Bay on the north, and the Atlantic border deposits on the eastern, several such diameters may be run across. From the heights observed (p. 196), and the distances between any two of them, the mean rate of increase per mile of distance may be obtained. The following tables contain the results of such comparisons—substituting New Haven, Ct., or New London, Ct., for the north shore of Long Island Sound.

A. Lines running toward Montreal.

	Distance.	Rate.
New Haven to Montreal	300 miles.	1·66 feet per mile.
Point Shirley to Montreal	255 "	1·65–1·75 "
Lewiston, Me., to Montreal.....	195 "	1·5

B. Lines to Murray Bay.

New Haven to Murray Bay, Canada	460 miles.	1·25 feet per mile.
Point Shirley to Murray Bay	375 "	1·33–1·40 "
Lewiston to Murray Bay.....	260 "	1·44

C. Lines to localities on the Atlantic Border.

New London to Lewiston, Me.....	220 miles.	0·9 feet per mile.
Sankaty Head to Lewiston, Me.....	192 "	1·05 "
Point Shirley to Lewiston, Me.....	125 "	1 to 1·2 "
Sankaty Head to Point Shirley.....	70 "	0·5 to 0·8 "

The mean rate of increase toward Montreal is thus 1·5 to 1·75 feet per mile. while on the coast it is not over one foot a mile; and in the direction of an intermediate point, Murray Bay, it is 1·25–1·40 feet per mile. The *direction of greatest increase is not in the direction of a meridian, but along a line running northwestward.*

From these mean rates of increase, supposing the increase uniform, the amount of change at intermediate points on the lines may be obtained. We thus obtain for the region of the Connecticut Valley at Lancaster, using the line from Lewiston to Montreal, a height of 318 feet. Using thel ine from New Haven to Murray Bay for a similar calculation, the height for the same place is found to be 326 feet. This near coincidence seems to be significant.

For Haverhill, the amount of change would be—the place being 46 miles from Lancaster, measured along the valley, and 198 from Long Island Sound—272 feet.

We thence have 1·25 feet per mile (=50 seconds nearly in angle) as the mean rate of change northward along the Connecticut valley.

The line D S on the section (figure 2, Plate 2) represents the mean-tide level thus deduced. It is drawn from a point on the Sound marking 25 feet above mean-tide level (supposing the change on the Sound to be 25 feet, though along by the mouth of the Connecticut it may not have exceeded 15 feet), and rises in the direction of the valley northward, at the rate of 1·25 feet per mile.

It cannot be assumed that the rate was equable throughout the valley. It may have been less than the deduced rate to the south, and greater northward; and this is shown beyond to have been probably a fact. If the rate had been one foot per mile for the first third of the length of the valley, or to Springfield, and 1·33 feet for the rest of the way to Haverhill, the height at Haverhill would have been very nearly the same as above deduced, or 268 feet.

b. Effects of the change while the river was low.—If the river were, for a while, at or near modern low-water level (and it probably was so), the change of 1·25 foot a mile, would have taken out all the mean slope from the several parts of the valley, excepting the abrupt descents at the falls. The tides would have extended beyond the Holyoke dam, eight miles above Springfield, obliterating the falls and have stood 15 feet above its top; and have reduced Turner's Falls nearly 30 feet in height. The elevation of low-water level above the sea would have been only 35 feet at South Vernon, or the Massachusetts boundary: at Windsor, 83 feet: at Haverhill, 120 feet Hence the descent between South Vernon and Windsor would have been only 48 feet, which is three feet less than the fall (51 feet) at Bellows Falls, situated between these two points: and the descent between Windsor and Haverhill would have been only 37 feet, which is three feet less than the fall (40 feet) at the falls between Hanover and White River. Since these falls would have wasted, by friction at bottom, any velocity which might have been gained by descent, the Connecticut River would have been for the most part a series of nearly still-water stretches with falls at a few distant points. This condition would have continued, with but little change as to the effect of the dams, after the waters had risen 20 to 25 feet above low water, as in a modern flood.

One possible consequence from such a state of things would have been an opportunity for clay and fine-sand depositions, without the need of help from dams; and another, an almost complete absence of the work of erosion—since the waters would

have had but slight working force, and the present low-water level would have been the lowest possible level at which this little work could have been done. An earlier consequence might have been—the deposition of the till with no more stratification where it fell into the waters than when dropped outside of them.

c. Effects of the change after the flood had made progress.—When the river had risen to a height of 60 or 80 feet above low-water level, the falls in the course of the valley would no longer have been mere nullities as regards their effect on the mean velocity of the stream immediately below them; for the velocity acquired by the descent would have been only in part wasted by friction at bottom.

But when, beyond this, maximum flood level had been reached, so that the surface of the water was 200 feet and more above low-water level, the falls would have lost all influence on the velocity by their submergence, and the general slope of the flood would have conformed nearly to the general pitch and width of the valley. As the upper deposits were made by the stream when near and at this maximum level, and the lower were, at the same time, beneath the sweeping flood, it becomes of the highest importance to compare, as nearly as possible, the mean velocity at the time with the amount of transporting power indicated by the nature and condition of the stratified deposits.

If the rate of change along the valley with reference to the ocean level were, as above deduced, 1·25 feet per mile (and the change at the Sound 25 feet,) the height of the water-surface above mean tide would have been at—

Haverhill	383 feet.
Windsor	299 "
South Vernon,	236 "
Springfield,	135 "
The Middletown dam	137 "

The mean slope and velocity on the above supposition, would hence have been for the part from—

	Distance in miles.	Slope ft. per m.	Velocity, with width 4000 ft. m. per h.	Velocity, with width 4000 ft. ft. per sec.	Velocity, with width 2500 ft. m. per h.	Velocity, with width 2500 ft. ft. per sec.
Haverhill to Windsor	41	2	11·515	16·89	11·39	16·70
Windsor to South Vernon	49	1·3	10·33	15·15	10·22	15·00
S. Vernon to Springfield	44	2·3	11·93	17·50	11·81	17·32
Springfield to Middletown	38	0	----	----	----	----
Haverhill to Springfield	134	1·9	11·37	16·67	11·25	16·50
Middletown dam to Sound	26	5·2	14·65	21·49	14·51	21·28

According to the above, the river at maximum flood would have had no slope between Springfield and Middletown, and have therefore been in this part a great lake. But this condition

is shown to be improbable by the coarse character of the deposits in the Springfield region that were made at maximum flood; and this is one of the reasons referred to on page 198, for believing that the slope in the lower third of the valley was reduced to a less rate than 1·25 feet per mile. Taking it at 1 foot per mile to Springfield, as there suggested, and 1·33 feet above Springfield, it gives for the height of the water-surface above mean tide at

Haverhill	387 feet.
Windsor	307 "
South Vernon	248 "
Springfield	151 "
The Middletown dam	144 "

Excepting south of Springfield, the changes in slope thus introduced between the places mentioned are small—that from South Vernon to Springfield becoming 2·2; from Windsor to South Vernon 1·2: that from Haverhill to Springfield, 1·8: and that from Haverhill to Windsor continuing at 2; so that the velocities would be but slightly altered. Between Springfield and Middletown the pitch becomes about 3 inches a mile.

According to the preceding table, the velocity from Haverhill to Springfield, notwithstanding this change of one-third in the slope of the stream, would still, when at the highest flood-level, have exceeded 10 miles an hour for a mean width of 2500 feet, the pitch to Springfield being nearly 2 feet a mile.* And if we assume that bends and other obstructions, and transportation would have reduced the mean velocity 20 per cent, it would still be 8 miles an hour, with a bottom velocity over 6, and therefore much in excess of that indicated by the character of the bottom deposits.

It is quite certain that the slope must have been much less than that which corresponds to a height of water-surface at Haverhill of 387 feet, or a pitch in the valley to Springfield of 21 inches a mile. But it is not so evident what slope would harmonize the facts; that is, would cause a velocity sufficient to make or leave coarse valley deposits near and at flood level, such as might be made by a current of 4 to 6 miles an hour, and, at the same time, leave almost undisturbed beds of sand or of fine pebbles along its bottom, whether at depths of 50 or 150 feet, this alike for the stream north of South Vernon and south of it, and even for the part north of Wells River to Barnet as well as south of Wells River.

By calculation, using the same elements as before, taking the width at 2500 feet and making no allowance for ob-

* According to the formula, the velocity varies approximately as the 4th root of the slope, and, consequently, to diminish the velocity from any rate to one-half, the slope must be reduced about a sixteenth.

structions by bends or transportation, it appears that a slope in the water surface of only 0·383 inches a mile would give a mean velocity of 4 miles an hour; and one of 0·923 inches, a mean velocity of 5 miles. The Mississippi along a straight portion at Carrollton, during high water, when the *maximum* depth was 136 feet and the slope but 1·3 inches, has a mean velocity of 4 miles per hour. (See beyond.)

Making allowance for the probable amount of resistance from the sources above mentioned, it would seem that a slope of 2 inches a mile to Springfield would have been sufficient to meet the conditions; and that one of 3 inches would have been too great. But suppose it 3 inches a mile; a change in the pitch of the valley amounting to 18 inches a mile would have been needed to produce it. If we suppose it 6 inches—which is a very large pitch in any stream under continuous flow (that is, not broken into parts by dams) which was the fact with the flooded Connecticut down to Middletown—the needed diminution in the pitch of the valley would have been 15 inches a mile. This amount, 15 inches, added to the 15 inches a mile deduced from the elevated sea-beaches, would make for the total diminution in mean rate of pitch to Springfield $2\frac{1}{2}$ feet a mile: and if the amount were 18 inches, the total would be $2\frac{3}{4}$ feet a mile, which would make the change at Haverhill hardly 50 feet less than at Montreal.

The later change, whatever its amount, would have been a continuation of the former. Whether it was confined or not to the Connecticut valley—a line of weakness in former geological eras—must be determined by the study of other valleys to the east and west, especially the Merrimack on one side and that of Lake Champlain and the Hudson on the other. It is a strange fact that the terrace formation of the southern part of the Lake Champlain region, and of its continuation along Lake George to Albany on the Hudson has not yet been carefully studied.

In view of so great changes in the slope, reining in the waters, the floods of the Connecticut Valley lose something of the magnificence portrayed in the high terraces. But, on the other hand, the conditions are brought within more reasonable, or less improbable, limits.

It is interesting and instructive to compare, in this connection, the velocity and other elements of a straight portion of the Mississippi River at high water. According to the measurements of such a portion of the river in the vicinity of Carrollton,* referred to above, made by the Delta Survey in 1851 under the special charge of Professor C. G. Forshey, and published on page 316 of

* Carrollton is 121 miles from the mouth of the Mississippi, and at high water the surface of the river is 15·2 feet above sea-level.

the report of Humphreys and Abbot as one of the thirty cases upon which data their formula for velocity was based, the elements were as follows:

Area of cross-section in square feet.	Width in feet.	Wetted perimeter in feet.	Maximum depth in feet.	Mean velocity per second.	Slope.
193,968	2653	2693	136	5·9288	0·00002051

The *calculated* velocity found by the formula was 5·9673 per second, giving a difference of 0·0385 feet. The velocity obtained is almost exactly four miles an hour; and the slope to which this velocity corresponds is, as already stated, 1·3 inches per mile.

By means of the formula, we have, from the same conditions in the Mississippi as to dimensions, but with other assumed slopes, the following results:

Slope per mile in feet.	Slope per foot.	Velocity in miles per hour.	Velocity in feet per second.
1·75	0·0003314	8·129	11·918
3·0	0·0005682	9·32	13·670
4·5	0·0008523	10·32	15·145
6·0	0·0011364	12·47	18·292

The case of the Mississippi differs from that of the flooded Connecticut in the less average depth—the *maximum* being 136 feet. The Mississippi River was more like the New England stream when it was itself flooded from the same cause; when its loess deposits were formed, according to Professor E. W. Hilgard, not many miles above the head of the delta, to a height of 450 feet above the sea. Its average width below the mouth of the Ohio exceeded 50 miles. Professor Hilgard points out the fact* that the "Grand Gulf Group," of the border of the Gulf of Mexico, along, and east and west of, Louisiana, (representing the Tertiary after the Eocene,) is capped near the gulf by beds of stratified drift to a height of 500 feet above the gulf; and that the facts indicate that an elevation of the gulf border, and of that portion of the Mississippi valley, was begun in the early Tertiary and went on until it had reached a height in the Glacial era of 900 feet, after which there was a reverse movement. In that reverse movement (or after it and a new bend upward), the region must have been long at or near 450 above the sea (if there was not, in place of part of it, a diminution of pitch northward), in order that the slope of the water-surface of the river should have been reduced to a minimum, so as to allow of such fine deposits as the loess.

On this view, the Mississippi had a dam, and was put thereby into a lacustrine condition, right for making loess or loamy deposits. The Connecticut had a dam also; but it continued nevertheless to be a river throughout, its loamy deposits and clay-beds being subordinate in the upper terraces to its sand-beds and those of coarser constitution.

* In this Journal, xxii, 58, 1881.

[To be continued.]

Art. XVIII.—*On the Geographical Distribution of certain Fresh-water Mollusks of North America, and the probable causes of their Variation*; by A. G. Wetherby, Professor of Geology and Zoology, University of Cincinnati.*

Having set forth, in the first part of this paper, the main facts connected with the distribution of the *Unionidæ* and *Strepomatidæ*,† over the region under consideration, it now becomes my task to attempt a solution of some of the problems thereby indicated; for, to the careful student of this subject, several of its features are in the nature of unanswered questions; and these, it seems to me, will be found to be so intimately associated with the history of our continent's development, and especially with that part relating to the evolution of its systems of drainage, as to cause continual reference to that subject, in the light of present geological knowledge.

Without stopping, at this point, to discuss the zoological relationships which possibly indicate the marine ancestry of the mollusks under consideration, it is a fair presumption that *the first fresh-water forms were lacustrine.*

Of the truth of this proposition there seems to be ample evidence in the fact, that, even during Archæan times, fresh-water lakes were not impossibilities or even improbabilities. The processes by which salt water areas, isolated from the main ocean, pass through their various stages of approach to fresh-water conditions, are familiar to all students of physical geography; nor is the fact of the existence of such bodies of water in areas of limited drainage any less well known. High plateaus and low plains alike contribute examples of this fact. They are most typical in regions of comparative aridity from various causes; and many such bodies of water now known have been undergoing the freshening process since the early Tertiaries.

It can not, I think, be doubted that there have been, throughout the geological ages, depressions of this description; and when we consider the fossil shells found in lacustrine deposits, and the forms now inhabiting such bodies of water as Lake Baikal and Lake Balkash, the probability of their gradual differentiation from marine types, and of their successive variations as fresh-water forms, seems to be associated with no factor of the improbable.

In this consideration due weight must be given to the great

* From the Journal of the Cincinnati Society of Natural History, July, 1881; being Part ii of an article of which Part i appeared in January, and was noticed on p. 76 of this volume.

† The Strepomatidæ comprise the American species formerly referred to the Melania family.

influence of Archæan lands upon the subsequent moulding and forming of the continent, whose final systems of drainage, and all the stages of development leading to them, were determined by this early and stable region, which had its representative areas on both sides of the incipient uplift, and at comparatively isolated points over the great central basin; areas around which clustered, throughout the history of continental progress, the geological activities that determined everything.

It seems desirable, in discussing the variations above hinted at, to remember that there must have been a far greater impetus given them, when changes in drainage brought to these creatures the vicissitudes accompanying distribution into bodies of flowing water. Such changes of station, and finally of habitat, were among the last possibilities of continental growth, because it was only in connection with the later grand movements associated with terrestrial evolution, that present systems of drainage became possibilities. It is likewise true, that at no time since any drainage has existed on the continent in streams large enough to contain a shell fauna, has there been such a complication of circumstances favorable to the local variation of that fauna, and the consequent establishment of varieties as now. For while it is a well determined fact in geology, that, with the progress of continental evolution, the complexity of the characters of strata increased, it is also true that each of these new features would become a factor of importance in modifying the character of streams flowing through the land, and would, for this reason, aid in changing the nature of the mollusks inhabiting them. And these conditions reach their greatest development in mountain regions, for the following among other causes that may be enumerated.

First, it is in such areas that streams cut their way through strata of the most heterogeneous character, partly owing to the effects of metamorphism and other disturbing causes upon strata that may have been, originally, more homogeneous. *Second*, because even where metamorphic effects may be wanting, the range of formations traversed will be greater through the more extensive erosion. *Third*, because in mountainous regions there is an increase of probability that mineral deposits will fall in the path of streams, which will effect changes in the water, causing abnormal stunting, or extraordinary development, of given forms. *Fourth*, because the influx of side streams, bearing the water of mineral springs, will add to these effects. *Fifth*, because here we have the maximum of extremes in rate of current, and consequently the maximum of capacity to transport sediments that may act favorably or unfavorably upon the various creatures inhabiting these streams. *Sixth*, because of the probability that these mollusks have been propagated down stream, to the limit of favorable conditions—a

limit always determined in the first place by geological causes —and because of the variation in the conditions met in this traverse. *Seventh*, because combined with these circumstances is the fact, that all the stages in the development of these creatures are passed in an element thus unstable, amid conditions thus diversified, where the slightest tendency to variation must have the maximum of exciting causes constantly operating to call it into play. If, then, it be admitted that there is in the animal races any tendency to variation, and any capacity for adaptation, life, under such circumstances, would be a continuous development and exercise of these inherent qualities. For mountain regions have been the seat of origin of all drainage, and, no doubt, of the first forms of life inhabiting that drainage.

Now let us examine these probabilities in the light of the actual facts connected with the distribution of certain fresh-water shells.

First, we may consider the circumpolar distribution of the *Limnæidæ*. These mollusks are essentially *lacustrine*, for while they are distributed into rivers and smaller streams to some extent, their station of fullest development is in lakes, the world over.

The genera, *Physa*, *Limnea* and *Planorbis*, are essentially northern forms, for it is in the cooler regions of the earth that they reach their largest size and greatest differentiation. Distribution southward is accompanied by a stunting of forms in all cases but that of the sub-genus *Bulimus*, of which the *B. aurantium* passes through the American tropics, and is many times the size of its circumpolar northern relative, the well-known *B. hypnorum*. This case stands as the only exception to an otherwise universal rule, respecting a group of mollusks covering many described species, and yet one in which the differentiation of forms has led to such interminable varieties, that the most critically accurate of our conchologists hesitate to label them. The careful student of our North American forms will find these shells more closely allied to their European relatives than any other group of mollusks found on the two continents, unless it be the *Succininæ*, and a few littoral marine species; and, as it is not possible to separate them *inter se*, upon anatomical distinctions, in the greater number of cases, it may be regarded as a substantial proof of their high antiquity when taken in consideration with the following facts: first, their universal presence in the lakes of the older geological formations at the north; second, their circumpolar distribution; third, their presence in regions unfavorable to the development of other families of mollusks, as testified by their absence; fourth, their persistent appearance together, even southward,

over regions of elevation. For these reasons, and for others of convenience in this discussion, I shall designate them as Fauna A, and will add this important and distinctly proven statement: that they reach, on our continent, their maximum of size, of differentiation, and the greatest local number of so-called species, in precisely that portion of it having the greater number of lakes, in regions of the oldest land or contiguous to it, and where there is the greatest paucity of other mollusks. This fauna is thus clearly shown to be regional, and the inference is fair that it has a very high antiquity.

Over the same region, both in Europe and America, we have distributed a few species of the *Unionidæ*, mostly represented by the genus *Anodonta*, a lacustrine group, always affecting still waters with muddy bottoms. These forms, with plain surface, and comparatively thin shells, are the predominant types of the Unionidæ over the whole northern portion of our continent from Maine to Oregon. It is among the species of this genus that there occurs the greatest apparent synonymy, and the systematic zoologist will find himself, in the study of these shells, face to face with the question of varieties in endless and interminable confusion. Nor is this statement an exaggeration, when we remember that European malacologists, of greater or less repute, have made nearly one hundred synonyms for the *A. cygnea* alone; and that the slightest review of our North American species, in the light of the evidence offered by geographical varieties, now well known, must reduce the number of so-called species more than one half; and many of these varieties continue from Eastern New York to Minnesota, and a fewer number, southward to the very borders of Mexico, *over all of which area I have traced them!* These shells, for like reasons with the first, I shall designate as Fauna B.

The region occupied by A and B contains very few representatives of the *Strepomatidæ*, or Fauna C. Their geographical range northward was set forth in the first of these papers; and it is a significant fact that the few species of the *Strepomatidæ*, occupying this region, are those belonging to types that farther south, where the conditions of variation enumerated in another part of this paper reach their maximum, are so intimately united by varieties as to render their separation into distinct species, in most cases, utterly impossible; as the shells from different localities are so completely blended, that it is no exaggeration to say that fifty per cent of the described species are the merest synonyms. At the north, even, the difficulty begins; and it vastly increases in the more southerly mountainous region. This fauna differs essentially from A and B, in that it is not, normally, lacustrine, but fluviatile. A very few species are found in lakes, occasionally; but there is in these

shells an inherent aversion to still water, which characterizes all the genera, leading them to frequent rather the rapid parts of rocky streams; and here it is that we meet their greatest diversity of types, and the greatest variety of coloration and ornamentation. This peculiarity of station is so persistent, that no skilled collector ever searches for them in level reaches of deep water, unless in the case of a few species of *Pleurocera*, which affect such localities; but *Io*, *Angitrema*, *Lithasia*, *Anculosa*, *Schizostoma*, *Goniobasis*, and *Strephobasis*, all genera represented by an infinity of varietal forms, seek always clean, rapidly flowing water, in rocky or gravely river beds; and these groups are only represented by the genus *Melanopsis*, over the same range in Europe and Asia, and by *Goniobasis* and *Pleurocera* at the north, in America, their grand metropolis; in foreign lands their representatives, also, are confined to a range mostly south of that occupied by A and B. This fauna has a very limited distribution of genera and species west of the Mississippi, a fact easily traced, I think, to true geological causes, some of which are past, and others are now in operation.

The shells designated as Ohio River Types in my previous article, I shall call Fauna D. Of its geographical distribution, varieties, and persistent forms, enough was said in that paper; and since it was written, I have received, from the very southwestern borders of Texas, a collection of Uniones gathered at random, which contains nothing but absolutely typical Ohio River species. South of the Ohio, in parallel streams, beginning with Kentucky River and Green River, and continuing to the eastern and southeastern tributaries of the Tennessee, we find, as has already been stated, a group of shells of a distinct facies, requiring no expert knowledge of conchology to enable one to see that it differs, as a whole, from the Fauna D, with which it is associated. Its southern distribution is coëxtensive with that of Fauna C, in all the larger and many of the smaller streams. Here occurs the greater number of described "species" of the genus *Unio;* for among the forms filched from these prolific streams, malacological enthusiasts have disported themselves as species-makers, until the crying need of our times is an honest, impartial, and thorough review of the whole subject. The approximate boundaries of Fauna E may be placed between the Ohio River on the north, the Tennessee on the south, the Appalachians and the Mississippi. One fact is of curious import here; and it deserves to be put upon record in this discussion, and in this place. In his last edition of his Synopsis of the Family Unionidæ, 1870, which he tells us is his "most important work," Mr. Lea makes the following remarkable statement, the truth of which he had abundant opportunities to verify: "although I have examined critically,

and published descriptions of the soft parts of 254 species of this family, and have often dissected 50 to 100 of the same species, I can not see, as yet, any useful division that could satisfy the student or the adept, which can be made by systematic difference in the organic forms of the soft parts." This means, I suppose, that the differences of the soft parts are so small as to afford no safe basis upon which to predicate classification. I may add to this, that the most intimate study of the anatomy of different species of the *Limnæidæ* and *Strepomatidæ*, has convinced me beyond reasonable doubt, that specific differences, supposed to be indicated in the shells, do not extend to the animals themselves, so far as these studies go to show. I have now in course of preparation a memoir on this subject, which I hope soon to publish with accurate anatomical illustrations. Here is one of those strange facts, standing at the very threshold of the question of evolution, which finds a parallel in the *Lingula* and the *Rhizopod*.

We may now venture upon a few suggestions, to which these considerations give rise. Clearly the oldest shell fauna upon the continent would have naturally inhabited Archæan regions: and as it is altogether likely, from chemical facts associated with the deposit of iron ores, and the presence of graphite in the older rocks of the continent, as pointed out by Dr. Hunt and Dr. Dawson, that organic life may have existed to an extent not yet determined by fossils actually discovered as such, I think we do not pass beyond the bounds of probability in assigning to Fauna A a very remote antiquity. From its original *locus*, it has spread to the limit of suitable conditions, a limit undergoing constant variations, perhaps, through the geological ages, but which has been determined by boundaries mainly fixed by true geological causes. Through adaptation this fauna has, in a few cases, overstepped its primitive barriers, but it remains, as we have seen, true to its original instincts in all its more important phases. It is not probable, as may be suggested by the doubting reader, that this fauna would have been exterminated by the great glacier, which is supposed to have originated in its peculiar haunts, but more likely that the few species having an abnormal southern or southwestern range, received the first impulse of distribution in that direction from the glacial condition; and that, with the northward retreat of the glacier, they simply resumed their normal habitat, continuing their distribution in that direction, in succeeding times, to the northern lakes of British America. In studying Fauna B. we find evidence that a previous distribution, probably severed by the same or other causes, has never been fully united in a few cases—as in that of the *M. margaritifera*, occurring in Maine and Oregon, but not between these stations so far as now

known. But in most cases, the re-union has been complete. Such remnants as the Glacial epoch left, have been equal to the emergency of perpetuating their races over the region desolated by glacial action, and they may thus indicate what are the possibilities of development under determinate conditions. It may be suggested, that as the species of so-called *Strepomatidæ* of the west coast have rather the facies of the tropical Melanians, and as the other associates of the *M. margaritifera* in the waters of Oregon are species not elsewhere found, that this little faunal remnant is an independent one, and I readily agree to all this; yet there is no doubt of the existence of a Fauna B, or of its distribution, and the possibility that its present species are the descendants of a geological remnant like those of A. Still more striking is the evidence to be adduced from Fauna C. The region over which this group is distributed may have had some drainage, though perhaps slight, as far back as the epoch of the Cincinnati uplift. It thus may have continued through all the Paleozoic ages thereafter. What wonder, then, that we have here such diversity of forms, when we remember the mutations through which the continent subsequently passed to the termination of the Paleozoic. Local elevations and submergencies, and the various phenomena associated with the progress of continental development, brought to these creatures a series of vicissitudes that may have left many remnants in favored spots, whose descendants, modified and changed as they are, afford us the multitudinous varieties which this fauna assumes throughout its metropolis.

Indeed, if we could reach the ancestral form of these creatures, we should have another proof of the existence of what have been so philosophically called "comprehensive types;" and it is by no means a difficult thing to show abundant evidences of their presence in this heterogeneous host of their modified descendants, as I hope to point out hereafter. Even if this fauna does not antedate the Carboniferous epoch, the station which it has always occupied, for reasons already shown, would have brought a maximum of differentiating causes to bear. Nothing seems clearer to me than the separate origin of D and E. This is indicated by the merest superficial study of the shells, and I confidently expect that future geological explorations, among the western Tertiaries, may bring to light additional evidence upon this subject; and that when the habits and anatomy of these animals have been more thoroughly studied, and when we have a fuller understanding of the relations existing between the living and the fossil species of western Europe, and the fossil Tertiary species of southeastern Europe, new light will begin to break in upon the "origin of species" among these protean bivalves; for such work is the

special province of geology, and the highest generalization to which the perfection of geological knowledge can lead us.

In considering the facts connected with the exploration of the western lake basins, we find the *Unionidæ* to be distributed through the whole series of deposits from the Jurassic to the Tertiary, and well through the latter. In a very philosophical discussion of this subject, Dr. White has shown that there is an intermingling of forms, and an extent of differentiation pointing to remoter origin. But he has, in a foot-note on page 620, made the following statement which needs correction. "It is a significant fact that those North American rivers which contain the richest Unione fauna drain Mesozoic and Tertiary regions, while those that drain Paleozoic and Azoic regions have a comparatively meagre Unione fauna." The whole drainage of the Ohio is Paleozoic, or so nearly so that we may call it such. This stream and its tributaries south and southeast are the metropolis of these shells. And it is here that we find the two faunas above indicated most distinctly developed. The rivers draining the Mesozoic and Tertiary regions of the west have a very meagre fauna, both as to species and individuals; and I have already stated, that, with the exception of the few *Anodontas* of the northwest, the entire assemblage is composed of Ohio types. Until series of casts of the Ohio River shells are made, and these are carefully compared with the casts of species described from these western localities, we shall not have reached the best conclusion which a study of these fossils will afford us. If we consider the species of the Mesozoic and Tertiary regions of the south and southwest, we shall find that when we have removed the Ohio types from the lists, very few valid species remain. How absolutely true this is, and how great is the synonymy of these shells, I am sure is not the well understood fact in American malacology that it ought to be. There can be little doubt that the distinctively Ohio types, thus widely distributed, and so greatly differentiated, antedated any other forms occupying the same region with them. But other groups, during the mutations of the geological ages, left their remnants which have spread over the same area. The persistent species have either less tendency to variation, or the precise circumstances to call out such latent energies have not yet been brought into active account; while other forms, for opposite reasons, present us an infinity of varieties, always easily recognized, and of the derivative character of which no person, who has investigated this subject, can have any doubt.

In this connection the isolated fauna of the Coosa, to which reference was made in the previous article, must not be neglected. This stream flows through a comparatively limited drainage. It contains two genera, *Schizostoma* and *Tuiotoma*,

represented by thirty species, that have not yet been found outside of it; and this in a region where every stream contains an abundance of *Strepomatidæ*. How easy for a slight geological disturbance to obliterate the record of their existence; how easy to have an isolated remnant of this unique fauna left in the upper reaches of this mountain stream, when a less submergence than took place in this region during the Tertiary, would exterminate many contemporary species in the lower part of its drainage. In such a case, this isolated remnant, unique and strange, would present us with a problem for consideration like that of the *Unio spinosus*. This single example well represents the principle to which this article points, and shows how readily, in earlier times, when systems of drainage were comparatively limited, and opportunities for the spread of species were correspondingly less, there might have been many cases like that of the Coosa, during the various epochs, which left remnants of their shell-fauna; and those remnants, which had less tendency to variability, have persisted with comparatively little change; or, possibly, the changes have been in a direction which did not characterize other groups with which they were associated, leaving them distinct. At all events, the faunas are plainly indicated, and in many cases it is not difficult to point out central forms, around which they seem to be clustered.

The various other genera of Fresh-water Shells, found in the western deposits above mentioned, all exhibit a tendency to varieties equal to that of the *Unionidæ*. The species of *Goniobasis* (?), *Viviparus*, *Physa* and *Planorbis*, are all cases in point; but one can not help seeing how closely the three genera last mentioned are related in all these fossil forms to species now living; and it seems that Dr. White's remark, accompanying the description of the *Anodonta propatoris*, "It is not to be denied that its separate specific identity is assumed from its known antiquity, rather than proved by its structure and form," might have been, with still greater significance, written of many of these fossil *Viviparidæ* and *Limnæidæ*. Let this be as it may, I am convinced that the origin of these Tertiary and Cretaceous forms is to be sought in a Paleozoic progenitor, whose probable starting point was in regions adjacent to the western Archæan. While the species of fresh-water habitat may have persisted since the Carboniferous, in all the region between the Appalachians and the Mississippi, much of that portion of geological time has been fatal to such existence in the region west of the same stream: and though Mr. Tryon speaks of the Mississippi as a barrier to the westward distribution of species, it seems to me that the cause is really to be found in the character of the western tributaries as well; for while the

muddy waters of the Mississippi are an effectual barrier, in a general way, accidental transportation, or a few cases of actual traverse, that we cannot doubt must have taken place, would have furnished abundant types for spreading the species through our western rivers, if the conditions had been favorable; but they were not favorable, and consequently no such distribution has taken place. Hence it is, that the few species of shells inhabiting those streams, seem to me more likely to be the descendants of an ancestry of old date, and their general correspondence in form to the Ohio type, points to their community of origin. The Fauna E is here wanting; nor has it any representative. When we come to the consideration of the down-stream distribution of the species east of the Mississippi, we find the *Strepomatidæ*, as represented by their most characteristic genera, and Fauna E of the *Unionidæ*, to have a barrier in that direction. Here they cease, and beyond it, in the Tennessee, Cumberland, etc., we find mainly the Fauna D. Since this fact is general, it becomes one of high significance in this discussion, and stands as a unique evidence in favor of some of the suggestions here made; and it shows conclusively, that continuous water is not the only condition of molluscan distribution; and that the present station of *Io*, *Goniobasis*, *Anculosa*, etc., in mountain streams, and in the more rapid portions of these streams, is the result of the presence of conditions to which these creatures are by nature fitted; and while a few species are more cosmopolitan, owing to their greater capacity for adaptation, or to their remote ancestry, the great bulk of Fauna C has its range circumscribed as has here been indicated.

While the evidences upon which the theory of this discussion rests, from the geological and phylogenic aspects of the case, have been thus hurriedly cited, there is yet another argument, resting mainly upon an anatomical basis, which, as above indicated, I hope, after a while to bring out. So little is known of the close relations of these animals from this point of view, that I am of the opinion that the systematic zoologist will look with wonder and surprise upon the almost entire absence of structural unlikeness in animals, even in such matters as the distribution of the alimentary and circulatory vessels, that may be associated with the widest variation in the character of the shell. Nevertheless, there are cases in both these families, of structural differences as striking as the other facts which have led to this division of our shells into these highly characteristic geological groups; and to these evidences I shall direct attention in a future article.

Art. XIX.—*Description of a New Genus of the Order Eurypterida from the Utica Slate;* by C. D. Walcott.

In the February number of this Journal,* notice was given of the discovery of the fragmentary remains of a large Pœcilopod in the Utica slate and its identification with the Eurypterida, a provisional reference being made to the genus *Eurypterus*. A review of this and the genera of its order shows that none of them present the characters seen in the remarkable cephalic appendage from which the genus now proposed derives its name.

Echinognathus, n. g.

Endognathary limbs (one or more pairs) formed of eight or nine joints, six of which carry long, backward curving spines articulated to their posterior side. Terminal joint slender, elongate, acuminate. Surface of the body and larger joints of the cephalic appendage ornamented with scale-like markings, as in the genus *Pterygotus*. Type, *E. Clevelandi*.

Echinognathus Clevelandi.

Syn. *Eurypterus? Clevelandi* Walcott. This Journal, vol. xxiii, p. 151, 1882.

The only portion of the body discovered is illustrated by fig. 1. It appears to be the left side or half of the ventral surface of the anterior thoracic segment. The reference to the ventral surface is from the presence of a thin membranous

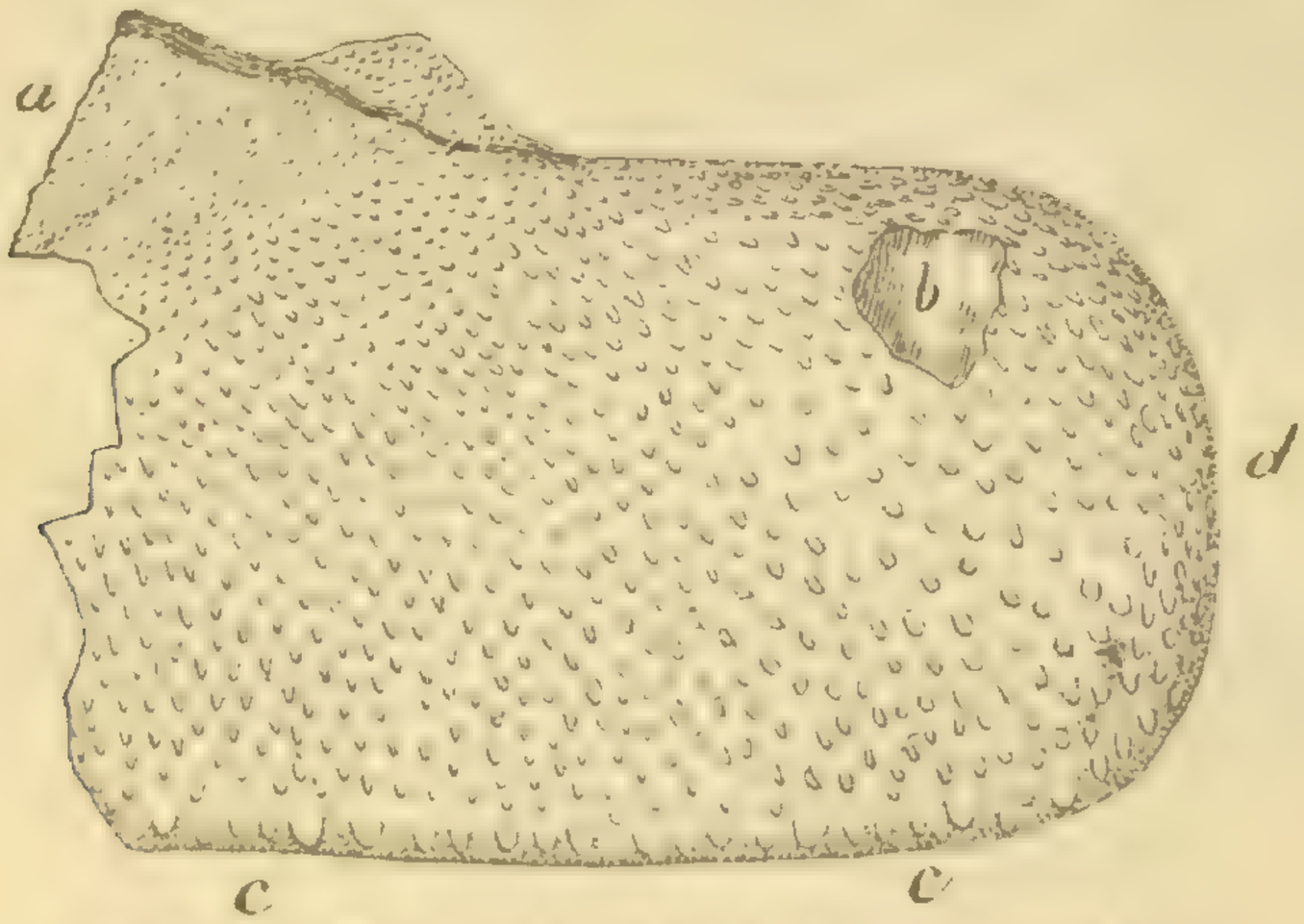


Fig. 1.—Reduced to 7-10ths the natural size.

extension of the anterior margin, a feature observed on the anterior segment of *Dolichopterus macrocheirus* Hall.† The test appears to have been thin and firm, and the margins are clearly outlined on the dark, smooth slate, while the surface is ornamented with fine scale-like markings on the anterior portion that increase in size toward the posterior margin (*c c*).

* Vol. xxiii, p. 151, 1882.

† Pal. New York, iii, p. 414*.

Figure 2, is a sketch, 7-10ths of the natural size, of the cephalic appendage as it appears on the surface of the slate and in the matrix. The entire length of the appendage from the point *a a* to the end of the terminal joint 7, as restored to its natural position, would be 12·5^{cm}, exclusive of the basal joint at *a a*. The long spines of the joints 3 and 4 are 5^{cm} in length.

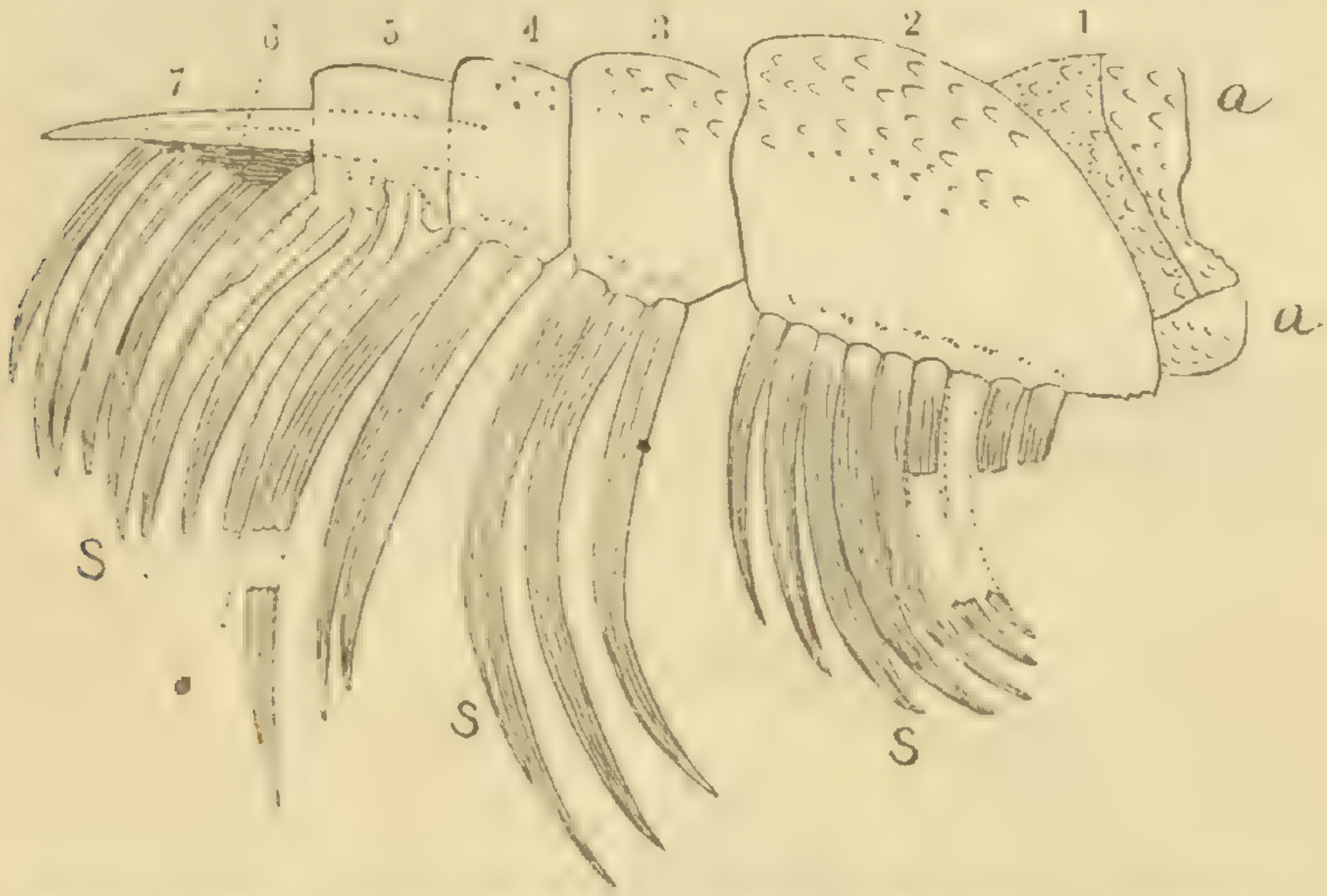


Fig. 2.—Reduced to 7-10ths the natural size. The joint (1) overlaps (2) and is broken away on its posterior margin. The line crossing it should be a slight ridge.

The joint marked (1) is broad and short with a rounded depression at the center of its inner margin. There is no evidence of the attachment of the long spines that are articulated to the posterior side of the succeeding joints. From the form of the joint and the presence of broken fragments of the test in the matrix at *a a* it is probable that it is the second joint of the appendage and that the first or basal joint is broken up. The joint (2) is large, elongate, rudely subtriangular, the long anterior margin curving around to meet the nearly straight posterior margin at its inner end. The latter margin has nine long curved spines articulated to it while the three following joints (3, 4) and (5) have but three each on their posterior margins. These joints (3, 4, 5), are more or less quadrangular in outline, (3) and (4) beng transverse and (5) a little elongate. The spines of (3) and (4) are the longest of any attached to the appendage. Beyond (5) traces of another joint are shown (6), and another is indicated by the position o the three curved spines beyond those of (6). These two latter joints were crushed by the forcing back of the long terminal joint (7), the inner end of which is seen beneath the center of the joint (4). This joint or terminal spine is slender, slightly curved backward, and marked by a slight median ridge and longitudinal striæ. The surface of the

joint (1) and the anterior portions of (2) and (3) show the scale-like markings observed on the fragment of the thoracic segment. If there were but one joint beyond the transverse joint (1), i. e. the basal, the entire appendage would have had nine joints, if our interpretation of the crushed joints is correct.

The long curved spines (*s*, *s*, *s*), are a very curious feature of the appendage and the most marked character of the genus and species. They are articulated to the posterior margin of the joints, as the latter rest flattened out in the slate or shale, and there is no evidence but that they formed a single series, as shown in the specimen and in the drawing, fig. 2. Each spine is constricted a little near its base, forming a rounded end or point of articulation: from this well out toward their pointed termination they retain an average width curving gently backward and inward. They appear to have been flattened when in a natural condition, and formed of a thin test which is rather strongly striated.

It is difficult to understand the purpose these spines served unless they are considered as having some relation to the branchial system of the animal. That they were used in securing food or carrying it to the mouth is not apparent, and no other use than the above is suggested from a study of the specimens we now have.

In the specimen of *Dolichopterus macrocheirus*, previously referred to, a few short, small spines are seen projecting from the posterior margins of the third, fourth and fifth joints of the third endognath. That they may represent in a greatly modified degree the spines shown in fig. 2 is not improbable. *Eurypterus punctatus* (Salter) Woodward, as restored in Woodward's Monograph of the Fossil Merostomata, p. 157, has a pair of long curved spines on four of the joints of the endognathary palpus, but they are represented as projecting forward, which does not appear to have been the case in the Utica slate species.

The character of the endognathary palpus of *E. Clevelandi* may indicate the approach to an earlier type of the Eurypterida, but from the characters shown by these remains and the fact that its size, estimating from the fragment of the thorax, was not less than 45 or 50^{cm} in length, and the approximate width 15^{cm} or more, it is evident that we must search deep in the strata of the Trenton group, or even lower, for the first members of the order.

As far as known to us the Eurypterida has not been represented hitherto on the American continent below the Medina sandstone of New York, and no described species is known below this horizon elsewhere. M. Barrande mentions the discovery of a fragment of the test of a Pterygotus in his étage D, 5,

at the close of the second fauna,* which would place it a little below that of the Medina sandstone.

The specific name of the species under consideration was given in honor of Rev. Wm. N. Cleveland, who obtained the specimens described in the Utica slate formation north of the village of Holland Patent, Oneida County, N. Y. On the same pieces of slate with them occur two characteristic fossils of the formation, *Leptobolus insignis* and *Triarthrus Becki*, and I have also obtained from the same locality and stratum of slate, *Dendrograptus tenuiramosus*, *Climacograptus bicornis*, *Schizocrania filosa*, *Endoceras proteiforme*, etc.

Several collectors have been and are now working in the Utica slate both in New York State and Canada, and a number of undescribed and interesting species are in their hands, as also several described from the Trenton limestone but unknown from the slate before. It is largely due to the persistent efforts of Mr. Chas. H. Haskell that the many localities in Oneida County, N. Y., have been discovered, and their rich fauna made known from the slate, from one of which localities the form we have described was obtained.

ART. XX.—*Notice of the remarkable Marine Fauna occupying the outer banks off the Southern coast of New England, No.* 4; by A. E. VERRILL. (Brief Contributions to Zoology from the Museum of Yale College : No. L.)

ECHINODERMATA (*continued*).

In the following list there are included 48 species. Of these, 22 have not, hitherto, occurred elsewhere on our coast: 26 have been found farther north, in the Gulf of Maine, or off the coast of Nova Scotia, and may be considered as arctic; at least 22 are European, and of these 18 or more are northern European; at least 14, and probably more, have been taken in deep water, in the Gulf of Mexico, or off Florida, by Pourtales and A. Agassiz, but there is, as yet, no general lists of their starfishes and ophiurans: of the whole number, only six are, so far as known, peculiar to this district, and probably this number will soon be reduced. Many of the species have a very extensive range, on both sides of the Atlantic, and also a great range in depth, occurring in much deeper water than was found at any of our stations. Species dredged only in less than 60 fathoms are not included.

In the list, the range of depth given applies only to this special region, as determined by the stations here included.

* Système Silurien Centre de la Bohême. I, supl. pp. 556, 557. 1872.

List of Echinodermata.

Holothurioidea.

THYONE SCABRA Verrill. 51–435 fathoms.

Stations 870, 871, 876, 877, 894: 919, 939, 943, 949, 1038: 1040, 1049.

TOXODORA FERRUGINEA V., sp. nov. 100–155 fathoms.

S. 870, 871, 873, 876, 877: 943, 949.

MOLPADIA TURGIDA Verrill. 120–182 fathoms.

S. 876 (1): 1026 (2).

Echinoidea.

SCHIZASTER FRAGILIS (Duben & Koren) L. Agassiz. 64–258 fathoms.

S. 865, 869, 870, 871, 873, 874, 876, ab., 877, ab.: 939–941, 943, 945, 950, 1025, ab., 1026, 1032, ab., 1035, 1036, 1038, ab., 1045.

SCHIZASTER CANALIFERUS L. Agassiz (variety?). 65–130 fathoms.

S. 871, 873, 874, 876, 877: 921–922 (9), 940, 941, 949.

BRISSOPSIS LYRIFERA (Forbes) L. Agassiz. 65–146 fathoms.

S. 870: 921, 1038. Europe and W. Indies.

SPATANGUS PURPUREUS Leske. 130 fathoms.

S. 940 (1 large, living). Europe and W. Indies.

ECHINOCYAMUS PUSILLUS (Müller) Gray. 146 fathoms.

S. 1038 (1). Europe and W. Indies.

ECHINARACHNIUS PARMA Gray. 10–219 fathoms.

S. 951, 985–989, very ab., 1038, many.

PHORMOSOMA SIGSBEI A. Agassiz. 458 fathoms.

S. 1029 (1 living). W. Indies (A. Ag.)

ECHINUS GRACILIS A. Agassiz. 86–146 fathoms.

S. 872 (2): 940 (7), 1038, 1039: 1046 off Delaware Bay, 3 large.

ECHINUS WALLISI A. Agassiz. (=*E. Norvegicus* in list of 1880). 258–458 fath.

S. 893, 894: 939, 1028, 1029.

TEMNECHINUS MACULATUS A. Agassiz. 115 fathoms.

S. 871. Gulf of Mexico (A. Ag.)

DOROCIDARIS PAPILLATA A. Agassiz (variety). 104–146 fathoms.

S. 1038 (1): 1046 off Delaware Bay (5).

Asterioidea.

ASTERIAS VULGARIS (Stimpson) Verrill. Shore to 208 fathoms (? 368).

S. 869: 917–920?, 994 (3), 1032 (1), 1035 (12), 1037 (12): 1046 (1), 1047: ab. in shallower water.

ASTERIAS TANNERI Verrill. 69–192 fathoms

S. 869–872: 922, ab., 923, ab., 940, 941, ab., 949, 950, 1035: 1047, ab.

STEPHANASTERIAS ALBULA (Stimpson) Verrill. 64–130 fathoms (? 192).

S. 865–867, ab., ? 869, 870–872: 921–923, 940, 949–950, ab., 1035, ab., 1036, very ab.: 1043, ab., 1046, 1047.

CRIBRELLA SANGUINOLENTA (Müller) Lütken. Shore to 115 fathoms.

S. 865–867, 871, 872: 949—commoner and larger, in shallower water, nearer the coast, S. 928, 933, 934, 956, 957, 985–987, 1009, 1036.

DIPLOPTERASTER MULTIPES (Sars) Verrill. 130–212 fathoms.

S. 869, 878, 895: 924, 925, 938, 939 (13), 940 (10), 945 (11), 947, 951, very large. 1025, 1026, 1032 (22), 1033, 1038: 1047.

PORANIA GRANDIS Verrill. 69–192 fathoms.

S. 869, 872: 923, 940, sev., 949, 950, sev., 1039: 1046 (9 j.)

PORANIA SPINULOSA Verrill. 192–368 fathoms.

S. 869, 879, 894, 895: 925, 938, 939, 945, 946 (10), 951, 998, 994. 1025, 1032.

PORANIA BOREALIS Verrill. (=ASTERINA BOREALIS V.). 192–225 fathoms.

S. 869, 879.

ODONTASTER HISPIDUS Verrill. 64–487 fathoms.

S. 865, 868, 869, ab., 871–873, 878, 879, 892, 894, 895, 921, 922, 940, ab., 946, 947, 949, 950, ab., 994: 1043, ? 1049 (1 j.).

ARCHASTER FLORÆ Verrill. 100–410 fathoms.

S. 869, 873, 879, 881, 895: 924, 925, 938–940, 943, 945, 946, 951, 997, ab., 1025, ab., 1026, 1028, 1032, 1033, 1038.

ARCHASTER AMERICANUS Verrill. 64–225 fathoms; ab. in 64–150.

S. 865–868, very ab., 871, ab., 873–876, very ab., 877, 879: 918, ab., 920–921, very ab., 940–941, very ab., 945, 949, 950, very ab., 1025, 1035–1037, very ab., 1038, 1040, 1043.

ARCHASTER AGASSIZII Verrill. 182–487 fathoms.

S. 879, 880, 881, 891–894, 895, 938, 939, 946, 947, ab., 952, 994, ab., 997, very ab., 998, 1025–1026, ab., 1028, 1029: 1049.

ARCHASTER PARELII Dub. & Koren. 225–487 fathoms; scarce.

S. 879, 892–894: 938, 939, 947, 952, 1028, 1 j., 1029: 1049 (6).

ARCHASTER TENUISPINUS Dub. & Koren. 368 fathoms. S. 994 (1).

ARCHASTER MIRABILIS (?) Perrier. 310 fathoms.

S. 939 (1). Gulf of Mexico (A. Ag.).

ARCHASTER ARCTICUS M. Sars. 183–310 fathoms.

S. 925, 938, 939, 946 (2), 951 (3), 1028, 1032, sev., 1033.

ARCHASTER BAIRDII Verrill, sp. nov. 388 fathoms. S. 952 (6).

LUIDIA ELEGANS Perrier. 51–192 fathoms.

S. 865–872, many large, 871 (17), 873, 876, 877: 919, 921–923, ab., 940–941, ab., 949, 950, 1035, 1036, 1038, 1047.

CTENODISCUS CRISPATUS Düben & Koren. 182–310 fathoms.

S. 879: 938, 939 (5), 1025, sev., 1026, 1032.

Ophiuroidea.

OPHIOGLYPHA SARSII Lyman. 30–368 fathoms (? 458).

S. 865–871, ab., 873, ab., 877, ab., 879, 895: 917, 918, very ab., 919, 924, ab. l., 925, 940, 943, 989–994, 991, ab., 1025, ab., 1026, very ab. l., ? 1029, 1032, 1033, ab. l., 1035, 1038: 1047.

OPHIOGLYPHA SIGNATA Verrill. 100–258 fathoms.

S. 869, 870 (10), 873, (24), 875, 877, 878: 939, 1038.

OPHIOGLYPHA (OPHIOPLEURA) AURANTIACA Verrill, sp. nov. 82–310 fathoms.

S. 869 (2), 872, 880 (2), 895 (4): 938, 939, 946 (6), 951.

OPHIOGLYPHA CONFRAGOSA Lyman. 238–506 fathoms.

S. 895 (1): 937 (1), 938 (2, large), 1028 (13), 1029.

OPHIOMUSIUM LYMANI W. Thomson. 238–500 fathoms.
S. 891 (11 j.), 892 (5), 895 (1), 994 (2).

OPHIACANTHA BIDENTATA Lyman=O. SPINULOSA M. & Tr. 192–202 fathoms.
S. 869: 945.

OPHIACANTHA MILLESPINA Verrill. 100–258 fathoms.
S. 869, ab.. 870, 871, 873, 895: 924, 925, ab.. 938, 939–940, ab.. 945, 951, 1026, 1032–1033, ab., 1034, 1035, 1038, ab.. 1039.

OPHIOPHOLIS ACULEATA Gray. Shore to 258 fathoms.
S. 865, 869, 871, 872, 879, 895: 920, 922, 924, 925, 939, 940, 943, 945–947, 949, 951, 986, 989, 1025, 1032, ab.. 1033, 1035, 1036, 1038, very ab., 1039, ab.: 1043.

AMPHIURA OTTERI (?) Ljungmann. 192–500 fathoms.
S. 869, 880, 891, 895: 997, 998, 999.

AMPHIURA ELEGANS Norman, var. TENUISPINA Ljung. 120–487 fathoms.
S. 869, 871, 876, 892, 894, 895: 1038.

AMPHIURA MACILENTA Verrill, sp. nov. (?=*a. Abdita*, young). 51–115 fathoms.
S. 865, 871: 919, 920, very ab., 921, 941.

OPHIOCNIDA OLIVACEA Lyman. 64–142 fathoms.
S. 865, 869, 871, ab.. 872, 873–877, ab., 878: 921, 940, 941, 949, ab.. 1040, ab.

OPHIOSCOLEX GLACIALIS Müller & Troschel. 115–238 fathoms.
S. 869, ab.. 870, 871, 879, 895: 924, 925, 939, 940, 945, ab.. 946, 951, 1025, ab. 1026, 1032, 1033.

ASTROCHELE LYMANI Verrill. 258–458 fathoms.
S. 938, 939, 1028, ab., 1029, ab.

Crinoidea.

ANTEDON DENTATUM (Say) V.=ANTEDON SARSII (D. & K.). 85–258 fathoms.
S. 869–871, 873–876, 878–880, 895: 925, 939, ab., 940, 943–946, 949, 1025–1027, 1032, 1033, ab.. 1035, 1038, very ab.: 1043, 1047.

The following species were taken by Lieut. Z. L. Tanner, in 1880, off Chesapeake Bay:

THYONE SCABRA V. S. 898.
SCHIZASTER FRAGILIS Ag.
ASTERIAS TANNERI V. 56 fath. S. 896.
ASTERIAS BRIAREUS V., sp. nov. 31 to 57 fath. S. 899; 900.
LEPTASTERIAS COMPTA V. 31 fath. S. 900.
DIPLOPTERASTER MULTIPES V. Two large specimens.
CRIBRELLA SANGUINOLENTA Lütk. 31 fath. S. 900.
ODONTASTER HISPIDUS V. 57 fath. S. 899.
ARCHASTER AMERICANUS V. 56 to 57 fath. S. 896, ab.: 899.
ARCHASTER AGASSIZII V. 300 fath. S. 898, ab.
OPHIOPHOLIS ACULEATA Gray. 31 to 57 fath. S. 899; 900.
AMPHIURA OTTERI (?) Lj. 300 fath. S. 898.
ANTEDON DENTATUM (Say) V. 157 fath. S. 897, ab.

Toxodora V., gen. nov.

Allied to *Chirodota*. Tentacles twelve, digitate. Skin thin, with scattered, slender, bow-shaped plates.

***Toxodora ferruginea* V., sp. nov.**

Body cylindrical, elongated, very contractile, liable to rupture. Skin somewhat translucent, filled with minute, reddish brown pigment-cells, and having numerous, minute, slender plates, in the shape of a bow, or a parenthesis, with the ends incurved. Tentacles stout, with numerous digitations. Length, 50^{mm} or more; diameter, 8 to 10^{mm}.

***Asterias Briareus* V., sp. nov.**

Arms variable in number; 10 in the largest example; long, slender; disk small. Radii as 1 : 9·5; lesser radius, 8^{mm}: greater, 76^{mm}. The rays have a strong dorsal ridge, and one lateral and a ventral one, on each side. Slender, transverse plates connect the dorsal and lateral ridges, leaving large spaces, in which are numerous papulæ, grouped in several clusters. Along the five ridges are long, slender, acute, rather distant spines; a few also stand on the cross plates; these spines are all similar and bear large, dense wreaths of small pedicellariæ near the base. Solitary pedicellariæ of large size and remarkable form are scattered between the spines, above and below: these are spatulate or hand-shaped, the wide tips terminating in five or six incurved claws, which interlock when the pedicellariæ are closed. Adambulacral spines slender, two to each plate, close to the ventral spines, with no intervening spines nor papulæ.

***Ophioglypha Sarsii* (Lütk.) Lyman.**

Two varieties of this species occur, which differ widely. The larger and smoother form, without prominent disk-scales, is found exclusively in the deeper waters, while the form with prominent, swollen disk-scales is abundant in the shallower localities (40 to 60 fathoms), though often found, also, at greater depths; the latter is the form that occurs abundantly in the Bay of Fundy and off Nova Scotia, where it grows to a large size, without changing its character. The two forms also differ in other ways.

I have seen a few four-armed specimens. Peculiar color-varieties are common.

***Ophioglypha signata* Verrill, sp. nov.**

Ophioglypha affinis Verrill, in former papers (*non* Lütken).

Disk varied in color, rounded-pentagonal, flattened above, or even concave when dried; covered with scales which form a distinct rosette; the dorsal surface is separated from the ventral by a marginal ridge, which becomes well-marked in dry specimens; notches, at the bases of the arms, slight, with an irregular and interrupted series of minute spinules; usually a short row

of small, slender spinules on each side of the notch, and a small, irregular, isolated group in the middle, sometimes nearly obsolete, or represented by only one or two small spinules, in the larger specimens; just below these there is a similar small group on the middle of the first visible arm-plate; the second arm-plate sometimes bears, also, two or more small spinules, but these never form a regular row. Disk-scales, when living, obscured more or less by a thin skin; the central scale and two alternating circles of five each, surrounding it, at a little distance, are round, darker colored and distinctly larger than those that intervene, which are small, but distinct, and often form rather regular circles around the larger scales: in the interbrachial spaces, near the edge, there are also larger scales: radial shields, irregular, long-triangular, their edges more or less covered by small scales, and separated by a rather wide wedge of small scales, in several rows. Oral plates, short shield-shaped, the breadth and length about equal; the outer and lateral edges form a regular curve, the inner edges make an obtuse angle. Mouth-papillæ, four on each side of each mouth-angle: the outer one is flat and broad, the others are slender, acute; the median papilla is larger, acute. The inner tentacle-pore is small and usually has a single small scale on each side; the others have one small scale. The arms are not very long, tapering to rather slender tips, with a median ridge. Ventral arm-plates widely separated, crescent-shaped, wider than long, those near the base with a proximal angle. Upper arm-plates raised into a distinct median ridge, with a slightly prominent outer angle; those near the base are much shorter than broad, distally they become much longer than broad. Arm-spines three, rather slender and acute, the upper one is decidedly longer and larger than the next, its length equalling two arm-plates; the lowest is much the smallest. The genital slits have a row of very minute spinules along the upper half. The color is variable; the disk is usually prettily marked by a rosette of brown or dark gray spots on a paler ground, or the darker tint may take a star-shaped form, with five or with ten rays, with the radial shields usually pale; or there may be a combination of the rosette and star; rarely the disk is nearly uniform pale gray, like the upper side of the arms. The larger specimens have the disk 10^{mm} in diameter; length of the arms, about 45^{mm}.

This species is rather common in this region, in deep water; we have also frequently dredged it farther north, in the Gulf of Maine; Bay of Fundy; and off Nova Scotia.

Antedon dentatum Verrill.

Alectro dentata Say, Journ. Acad. Nat. Science Philadelphia, v, p. 153, 1825.
Antedon dentata Verrill, Proc. Boston Soc. Nat. Hist., x, p. 339, 1866.
Alecto Sarsii Düben and Koren, Sv. Vet.-Akad. Handl., 1844, p. 231, pl. 6, fig. 2.
Antedon Sarsii Verrill, Amer. Journ. Sci., vii, p. 500, 1874.

This species was originally described by Say, from a specimen found at Great Egg Harbor, N. J. His description agrees in all respects so well with our smaller specimens, that there can be little doubt of its identity. Moreover, this form occurs in abundance off New Jersey, at moderate depths, but no other species has been taken there, unless in very deep water.

In addition to the numerous specimens from off Martha's Vineyard, we have it from Cashe's Ledge, off the coast of Maine, and from various localities off Nova Scotia, on the fishing grounds. Mr. A. Agassiz, also, took it, off our coast.

Anthozoa.

Of Anthozoa, upwards of thirty species were obtained. Among these are seven species of Pennatulacea and four of stony corals. A list of the species is deferred to the next number. Several very large and conspicuous species of sea-anemones or actiniæ occurred, some of them in great abundance. The following are among the more remarkable species, and appear to be undescribed:

Urticina longicornis V., sp. nov.

A large and very handsome species, remarkable for its parchment-like skin and long, tapering, pink tentacles. It contracts energetically and quickly. Column more or less cylindrical, or hour-glass shaped, usually higher than broad, very contractile, capable of involving the upper portion, which is, for about an inch below the edge (in large examples), softer, lubricous, longitudinally ridged, and brighter colored than the rest; below this the integument is firm, parchment-like, covered with small verrucæ, arranged in vertical lines, often fading out below, to mere wrinkles; the verrucæ are mostly due to the rising of the surface between longitudinal and transverse wrinkles. Disk large, in expansion broader than the column, usually concave. Tentacles not very numerous, large and very long, regularly tapered to slender, acute tips; they seem to be arranged alternately in two or three circles, concentrated toward the margin: the inner row contains only twelve, which stand well apart, and are larger than the rest. Mouth large, with eight large lobes on each side (or four bilobed ones): gonidial grooves large. Color of column, pearly white or rosy white, except the upper, softer portion, which is usually deep orange-red, or chocolate-brown, with paler stripes: disk rosy

white or pale pink, with narrow, deeper pink or purplish radii, which extend around and between the bases of the tentacles, but usually do not reach the mouth; lips reddish or orange-brown, striped with darker; tentacles usually light rose-red, or pink, translucent, often with brighter red on the inner surface and at tip, and frequently with an ill-defined ring of white at the base, and white at tips, outside. The larger specimens are 4 to 6 inches high; diameter of column 2·5 to 3 inches; across tentacles 4 to 6 inches; length of inner tentacles 2 to 2·5 long; ·12 to ·14 in diameter at base.

Taken in small numbers, and only in this region; 120–325 fathoms. It is a very elegant and showy species, and lives well in aquaria.

Urticina perdix **Verrill, sp. nov.**

Full-grown specimens are very large, often 8 to 12 inches in diameter, in expansion. Form very changeable. Column varying from low and broad to cylindrical and hour-glass shape, often higher than broad; integument soft and smooth, but in partial contraction sometimes covered, near the summit, with small, ovate verrucæ. Disk, in expansion, usually broader than the column, often with the edge broadly undulated or frilled. Tentacles translucent, rather long, and very numerous, forming five or six circles, the inner ones long (1 inch or more), tapered, obtuse, and placed about half way between mouth and margin, the outer ones smaller and crowded. Mouth with large gonidial grooves and strong lateral lobes. Color: column curiously mottled and reticulated with soft, yellowish brown, varying from a pale tint to deep orange-brown; the ground-color is pale buff and the two colors alternate in transverse bands, the darker bands usually wider, below, and often zigzag, or even broken up into squarish patches, while brown lines often cross the pale bands, giving an irregularly checkered pattern. These bands and spots are usually finer and more crowded above: disk usually pale yellowish olive, sometimes purplish, more brownish near the mouth, with faint alternating radii of lighter and darker tints: lips chocolate-brown, or red-brown; tentacles similar to disk, but paler, with two or three broad and ill-defined bands of brownish or purplish, one near the tip, faint, the basal one broader on the sides.

Ordinary specimens are 4 to 6 inches across the tentacles, in expansion, with the column 3 inches in diameter and about the same in height. This is a very handsome species and thrives well in aquaria. Several were kept by us all summer. It does not appear to extend to very great depths; 61–115 fathoms.

***Urticina callosa* V., sp. nov.**

A very large species, with a very thick, firm, leathery integument, covered, especially on the upper half, with irregular, often angular, large low verrucæ or ridges, which fade out into irregular wrinkles below; the verrucæ extend to the uneven edge of the disk, at the base of the tentacles, without any change in the character of the integument, which has a rather smooth, lubricous surface. Large specimens seldom retract the disk and tentacles completely, apparently owing to the firmness and leather-like stiffness of the walls of the body, but smaller ones contract more readily, and have a much smoother surface. The column is usually, in expansion, higher than broad, cylindrical, more frequently smallest at base or, hour-glass shaped, but when handled becomes more or less flattened longitudinally, or collapsed. Tentacles rather short, stout, obtuse, numerous, covering much of the disk, usually extending more than half way to the mouth, changeable in form, but not very contractile, often longitudinally striated or wrinkled. Disk large, usually much broader than the column, and commonly concave. Mouth large, with large, whitish gonidial grooves; side-lobes large, unequal, salmon-brown. Base broad, generally deeply concave, commonly enclosing firmly a large mass of mud, etc.; the base is capable of secreting a thin, chitinous pellicle.

Color, generally salmon or orange; column almost always pale salmon or buff, varying to deep salmon; disk most often deep salmon, with paler radii; lips darker salmon or orange-brown; tentacles usually plain deep salmon or orange-brown, with paler striæ. Height often 4 to 7 inches; breadth across expanded disk 6 to 10 inches; length of largest tentacles 1 to 1·25 inch; their diameter ·25 of an inch.

Very common in deep water in this region: 120–335 fathoms. Also northward, in the Gulf of Maine, and off Nova Scotia.

This large species is liable to be confounded with *U. nodosa* (Fabr. sp.), which is almost universally associated with it, has similar habits, and grows nearly as large. The latter can best be distinguished by having the retractile upper part of the column, for a short distance below the margin, smooth, soft, longitudinally ribbed and grooved, and covered with mucus, and highly phosphorescent, like the tentacles, while the rest of the column is firmer, coriaceous, not lubricous, and covered with irregularly scattered, prominent, often very large, rounded tubercles, disappearing below; there is usually a closely adherent, dirty coating over most of the surface: the color of its column is usually dirty whitish, or pale dull red, becoming brighter pink, or even chocolate-brown, on the smooth, upper part of the column: the tentacles are longer and more tapered, and, like the column, are much more retractile.

***Urticina consors* V., sp. nov.**

A delicately colored species, with a soft, smooth integument. Column elongated, in expansion; above, occasionally showing a few warts and longitudinal plications; margin simple. Tentacles numerous, in about four circles, crowded toward the margin; they are rather short and stout, tapered, acute, the outer ones much smaller. Mouth with strong, whitish, gonidial grooves at both ends, and about ten lobes on each side, separated by darker grooves. Color of body nearly uniform salmon, or rosy; tentacles a paler shade of the same, the outer ones with a flake-white blotch at the base, outside; disk pale salmon, with a pale bluish tint, and with flake-white radii, forking at the tentacles; mouth bright orange inside, with lines of reddish brown on the lips. Height, about 2 inches; diameter, 1·5.

All the specimens obtained were on the backs of a brilliantly colored species of hermit-crab (*Parapagurus*, sp. nov.), remarkable for large bright red patches on its legs; 160–458 fathoms. This species may not be a true *Urticina*. It resembles certain species of *Sagartia*, but no acontia were observed.

***Actinernus saginatus* Verrill, sp. nov.**

A large species, with a broad, low column, having a pale, translucent, thick, soft, cartilaginous, or gelatinous test. The column is broader than high, largest above, smooth, or more or less wrinkled. Tentacles not crowded, in two rows, close to the margin, long, tapering, rather slender, acute, decidedly thickened at the base; the outer ones have the thickened, outer, basal swelling continuous with the edge of the disk. Base much smaller than the column, concave, secreting a chitinous pellicle and enclosing a mass of mud, as in *U. callosa*. Color of column, pallid, or bluish white, with a tinge of pink; disk deep orange, with paler radii; lips deep orange-brown; tentacles orange-brown. Diameter of disk, in expansion, about 5 inches; of base, about 2; length of tentacles, 1·5 to 2 inches. The tentacles are contractile. Only one specimen was taken. Station 1029, in 458 fathoms.

***Adamsia sociabilis* V., sp. nov.**

A small, conspicuously colored, abundant species, which is always found on the back of a small hermit-crab (*Hemipagurus socialis* Smith). Color: column translucent, usually conspicuously striped with alternate pink and flake-white longitudinal bands, the latter narrowing upward; tentacles pinkish; mouth with pink lips, crossed by darker lines, between the small lobes. Height, in expansion, about ·5 of an inch (10 to 14^{mm}). **Common in 86–300 fathoms.**

Art. XXI.—*A New Form of Reversible Stereoscope*; by W. LeConte Stevens.

With a view to removing for others the difficulty implied in the binocular experiments on which I based the conclusions expressed in my recent papers, published in the November and December numbers of this Journal, I have devised the following form of stereoscope, which has been found quite satisfactory. Persons possessing no previous muscular training of the eyes have been able with it to secure reversion of relief in the combined picture as easily as they had obtained natural perspective while using it as an ordinary stereoscope. Some of my experiments involved extreme muscular tension; these required the use of the unaided eyes, but a large proportion of the rest can be performed by the aid of this instrument without special discomfort. It has been constructed for me by Messrs. E. & H. T. Anthony & Co., of this city.

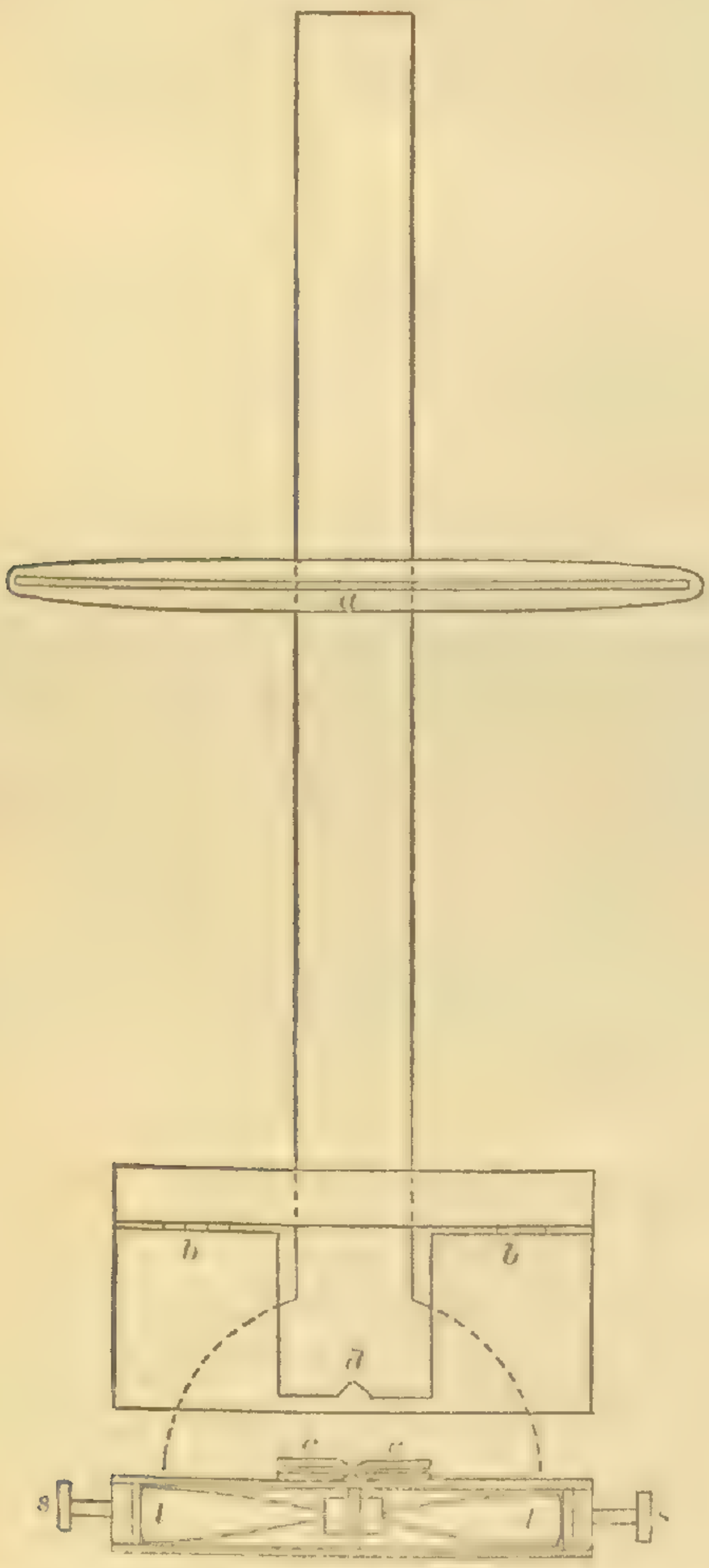
The semi-lenses (fig. 1, *l*, *l*), rest in a pair of boxes, with windows in front and behind, to transmit the light. These boxes are separated by a thin partition, on each side of which is a spring against which the thin edge of the semi-lens is pressed by the adjusting screw (*s*) at the base. In front is a pair of brass hinges (*c c*); when pressed flat as in fig. 1, each half of the stereograph is hidden from the eye on the other side; when folded, as in fig. 2, the whole stereograph is made visible to each eye. Attached to a sliding cross-bar is a wooden screen (*b*, *b*), moving on hinges; when this is pressed down flat, as in fig. 1, the view of the stereograph is unobstructed; when lifted up, as in fig. 2, the window at the middle permits the left half of the stereograph to be seen by the right eye, while the right half is obscured; and vice versa for the left eye. From the top of this window is a small projection (*d*). The stereograph rests upon its movable cross-bar (*a*) which slides upon a longitudinal strip about 30^{cm} in length.

The semi-lenses are easily removable at will, and a pair of prisms (*pp*) the refracting angle of which is 12°, can be substituted, but with their bases pressing against the springs instead of the screws.

To secure natural perspective through the semi-lenses, press the brass and wooden screens flat (fig. 1) and use the instrument as an ordinary stereoscope. Assuming the stereographic interval to be average, and the distance between the observer's eyes to be not greater than usual, comfortable vision will be secured by turning the adjusting screws until the semi-lenses are pressed as near as possible together. The light which enters the pupils then passes through the thicker part of each

semi-lens, and the optic angle is positive and small, or the visual lines may be sensibly parallel. If the observer's interocular distance is much greater than usual, the rays of light which he receives will be transmitted still nearer the base of the semi-lens, and slight optic divergence is necessary. This is avoided by giving a few leftward turns to the screw, permitting the semi-lenses to be pressed a little farther apart by the opposing springs. The same can be done to secure comfortable vision when the stereographic interval is great; pictures 10^{cm} apart can thus be viewed without discomfort, and without any very objectionable degree of coloration in consequence of want of

1.



2.

achromatism in the semi-lenses. By now turning the screws so as to press the glasses closer together, any degree of optic divergence may be attained that the observer is willing to endure, while the picture is still seen in natural perspective, distances being apparently slightly magnified, and diameters also in the same ratio.

To secure reversed perspective, lift up the wooden screen, fold the brass hinges outward in front, and substitute the

prisms for the semi-lenses, as in fig 2. Slide the stereograph nearly to the end of the stereoscope. Physiological perspective is at once reversed; whether this is enough to overpower the other elements of perspective must depend upon the nature of the picture. If the stereograph be that of the moon, the reversion is complete; if of terrestrial scenery, some objects may be apparently transposed in position while others are not. The same picture may be examined successively with each illusive effect several times in as many minutes. As soon as reversion is attained, the stereograph may be drawn up as close as may be convenient.

If both semi-lenses and prisms are discarded, the instrument becomes a direct-vision stereoscope; in some respects similar to that described by Professor William B. Rogers in 1855. To secure natural perspective, press the screens flat, pull the stereograph up as close as possible, and gaze as if through it at a remote object, with the muscles of the eyes relaxed. The two pictures, imperfectly focalized, are dimly seen apparently to overlap. The stereograph is then pushed out to the end of the stereoscope, and the pictures are binocularly combined by optic divergence. The stereograph may now be pulled up as near as convenient.

To secure reversion of perspective by direct vision, fold the brass hinges and lift the wooden screen, as in fig. 2. Push this out ($b'\,b'$) as near as possible to the stereograph at the end of the instrument, then pull it up, keeping the gaze fixed upon the projection (d') at the top. This grows dim as it approaches its previous position. Without changing the direction of the visual lines, except slightly to lower them, transfer the attention to the stereograph beyond. The combined picture is seen in reverse perspective, apparently much smaller and nearer than when the prisms were employed.

Those who have tried this instrument thus far have usually succeeded at the first attempt, for either natural or reverse perspective, when the glasses were used. Several trials are often necessary before success is attained by direct vision, but the variation in perspective thus attained is much more striking. But little experiment is needed to prove to any one who is thus successful that in the localization of objects in the binocular field of view presented by the stereograph, the current theory of successive triangulation by intersection of visual lines is inapplicable. The only substitute that covers the facts which the geometric theory fails to account for, is that of associated muscular action, which applies to divergence as well as convergence of visual lines.

The use of adjusting screws for the semi-lenses of the stereoscope is, of course, not a novelty. They were thus applied by

Duboscq, about 1850, to one of Brewster's stereoscopes and also subsequently by Helmholtz. A similar application is especially described by Professor Emerson in this Journal, Nov., 1861, and Emerson's stereoscope was for a number of years made by Messrs. Anthony & Co. of New York. It would indeed be difficult to evolve any wholly new principle in the construction of stereoscopes. The present instrument was devised for a specific purpose, which it accomplishes successfully.

40 West 40th St., New York, Jan. 21st, 1882.

ART. XXII. — *On the Magnetic Properties of a Specimen of Nickeliferous Iron from St. Catarina, Brazil, as first pointed out by Lawrence Smith, by* HENRI BECQUEREL;* *with a note by* J. LAWRENCE SMITH.

MR. LAWRENCE SMITH has recently discovered in a native iron, found in 1875 in the province of St. Catarina of Brazil, a singular physical property, viz: that in its natural condition it is very feebly attracted by the magnet, but if a fragment is heated to redness and subsequently cooled, there is manifested a magnetic property with the usual intensity of iron.†

The specimen which I have had occasion to study was furnished me from the collection at the Garden of Plants. A small bar was prepared, weighing 2·731 grams, and 18·5^{mm} long, 5·2^{mm} broad, and 3·8^{mm} thick. This bar was compared with a small bar of Swedish iron, of the same length and width, with about the same dimensions. The experiments made were by means of the electro-magnetic balance described in a preceding memoir.‡ The following results were obtained:

St. Catarina Iron.

Intensity.	Swedish iron.	Natural condition or heated to 230°.		Heated to redness.			Heated and tempered.	
Sine of the deviation of the needle.	Magnetic weight.	Magnetic weight.	Relation to Swedish iron.	Magnetic weight.	Relation to Swedish iron.	Relation to the native iron not heated.	Magnetic weight.	Relation to Swedish iron.
	mmg.	mmg.						
0·1500	60	3·2	0·053	64	1·066	20·	60	1·000
0·3000	238	12·6	0·053	244	1·025	19·3	232	0·974
0·5600	759	40·5	0·054	702	1·004	18·8	749	0·986
0·7000	1110	58·8	0·053	----	----	---	----	----
0·8300	1489	77·7	0·052	1489	1·000	19·1	1454	0·976

* Translated from Comptes Rendus, xciii. p. 794, 1881.

† Comptes Rendus, xcii, p. 848.

‡ Annales de Chimie et de Physique, 5th series, xvi. 1879. (Magnetism of Nickel and Cobalt.)

It is apparent, in the first place, that in the natural state, the small bar of St. Catarina iron is very much less magnetic than the Swedish iron. When the former was heated to 230°, it assumed a rose color, but the magnetic attractions on the balance were the same as before heating; when re-heated for an hour to a bright red heat, on lime, to avoid too much oxidation, and then slowly cooled, the iron was twenty times more magnetic than in its natural condition, and as magnetic as the Swedish iron. Its weight had been increased 35^{mg}. Finally, when heated a second time and plunged in cold water, its specific magnetism varied but very little, and remained the same after repeated heating and tempering.

To study this iron under conditions more or less removed from its magnetic saturation, two other little bars were experimented with.

Bar No. 2.—Weight, 1·245 gr.; length, 30 mm. breadth, 4 mm.; thickness, 3 mm.

Intensity.	Natural state.	Heated to redness.	Relation.
0·1525	1·7 (?)	36·	21· (?)
0·3000	5·	130·	26·
0·5600	16·	407·	25·4
0·8100	30·	749·	24·9

Bar No. 3.—Weight 0·273 gr.; length, 13 mm.; breadth, 2·25 mm.; thickness, 1·2 mm.

Intensity.	Natural state.	Heated to redness.	Relation.
-----	--	---	---
0·3020	1·8 (?)	41·	23· (?)
0·5600	5·	123·	24·6
0·8141	9·5	229·	24·1

The native iron of St. Catarina has been carefully studied by M. Damour and MM. Daubrée and Meunier, who have attributed to it a meteoric origin, and who have found that it contained about 34 per cent of nickel. The remarkable effect manifested when it is heated appears to be due principally to the presence of nickel and a crystallization effected at a very low temperature.

I therefore undertook a series of experiments, to see whether pure iron and pure nickel crystallized in the cold did not exhibit the same property. To try this, small cylinders of iron and nickel were prepared by depositing these metals upon a platinum wire by electrolysis. The deposit took place slowly at the ordinary temperature, and the deposited metals were crystallized. The bars were studied by the aid of the balance, then heated to redness and re-examined. The iron in the conditions under which I operated presented after heating no notable change in its magnetic properties. This was not true of the nickel crystallized in the cold, for it presented after the heating a considerable augmentation of its magnetic property. The following are some of the results obtained with this metal:

Nickel deposited by the pile.

First bar. Weight 2·442 gr ; length 40 mm.

Intensity.	Not heated.	Heated.	Relation.
0·1500	34 mgr	216 mgr	6·37
0·3000	147	589	4·00
0·4200	310	909	2·93
0·5900	589	1363	2·33
0·8500	1103	2043	1·85

Second bar. Weight 4·484 gr.; length 50 mm.

Intensity.	Not heated.	Heated.	Relation.
0·1708	80·5 mgr	434 mgr	5·39
0·2885	320·5	1010	3·15
0·5480	1132·5	2313	2·04
0·7758	1982·5	3470	1·75

The bars that were examined contained in their axes a platinum wire, thus forming a kind of tube; and as their section is small compared with their length, they are much nearer their point of magnetic saturation than the bars of native iron already examined. In regarding the rapid increase of the relation as recorded in the last column of the above tables, when we recede from the point of saturation, we recognize that the increase of the magnetic properties of the nickel crystallized in the cold is of the same order of phenomena as that observed in the St. Catarina iron.

It might be imagined, that on forming with the native metal bars such as No. 2 and No. 3, of which the sections are smaller and smaller in relation to their length, that we approximate to the magnetic saturation and would obtain numbers nearer to those which were found for the nickel in the condition of the preceding experiments: but on the contrary, in the case of these two bars, the magnetic relations before and after the heating is greater for the second than for the first. If the facts be considered which I have established in the memoir previously referred to, it will be recognized that the characteristics presented by the St. Catarina iron indicate that the magnetic conditions to which it has been submitted are far removed from those of saturation.

The magnetic capacity of nickel is greater in proportion to the distance the molecules of this metal are removed from each other; it therefore tends to become equal and even a little superior to that of iron. Perhaps the dissemination of the nickel in the mass of native iron under consideration is more favorable to the manifestation of the energetic magnetic property of this metal: in fact observation proves that after the heating of the nickel which accompanies the iron, the nickel behaves like the iron. The crystalline condition of the native iron not reheated appears as in the pure nickel to be the cause which opposes the magnetic manifestations.

We necessarily conclude from this research that the native iron from St. Catarina has been crystallized at a low temperature. This conclusion does not permit of forming a correct hypothesis of the meteoric or terrestrial origin of the iron.

Note by J. Lawrence Smith.

After completing my researches on the Ovifak iron and dolerite of Greenland,* which had occupied me off and on for several years, establishing indisputably the terrestrial origin of that iron, I was induced to examine into the nature of some other native irons, whose origin was somewhat equivocal. One that has been supposed to be of meteoric origin is that discovered, in 1875, at St. Catarina in Brazil. Having obtained specimens of this iron, I tried to apply to it the same rules of investigation as I had done to the Greenland iron, but my series of specimens would not permit of this and the question was left in doubt. My first object was to separate a pyritic mineral associated with the iron; but owing to the fact that the metallic iron permeated the pyrites in numberless filaments, it was impossible to conduct this separation by means of the magnet, nor have I as yet been able to devise any other method. While applying the magnet to various parts of the pure metal, it was found that many of these small pieces did not respond to the attraction of the magnet, but when these pieces were flattened out by being hammered between two bright surfaces, that the flattened metal would be attracted by the magnet, and if heated to redness would become as susceptible to the magnet as pure iron. The iron of the native mineral, as I had previously ascertained, contained as much as 34 per cent of nickel, but the mere presence of the metal in no manner sufficed for an explanation of this phenomenon; for the Oktibbeha meteoric iron contains over 45 per cent of nickel, and is under all circumstances affected by the magnet as readily as any other meteoric iron. I made a number of experiments, and satisfied myself that many pieces of the St. Catarina iron in its natural condition were *one or two hundred times* less magnetic than pure iron; in other pieces the difference was much less, but after heating they all became equally magnetic. Having no magnetic balance I sent a detailed account of my experiments to the French Academy of Science, with a request that M. Becquerel should examine it with his magnetic balance: this he has done and his interesting results are given in the pages preceding.

While he does not mention having tried the effect of mechanical compression on the crystalline nickel as deposited by electricity, it may be that this compression would have some effect in increasing its normal magnetism. I hope soon to investigate further this iron to settle the question as to its possible origin.

* Comptes Rendus, vol. xci, and Annales de Chimie et de Physique, 5e ser., xvi. 1879.

ART. XXIII.—*Origin of Jointed Structure in undisturbed Clay and Marl deposits;* by JOHN LECONTE. (From a letter addressed to Professor J. D. Dana, dated Berkeley, California, Jan. 10, 1882.)

My Dear Sir:—In reading Mr. G. K. Gilbert's very interesting and suggestive article on "Post-Glacial Joints," (this Journal, III, xxiii, 25–27, Jan., 1882), it occurred to me that the key to the true explanation of the jointed structure of the clays and marls, constituting the floors of the deserts of the Great Salt Lake basin, might be found in the analogous phenomenon, observed at the present time, in the desiccation of the fine sedimentary deposits forming the deltas along the Sacramento River and other valleys in California. The reclamation of the Tulé or swamp-lands of these deltas, by excluding the overflows of the rainy season by means of extensive levees, has brought under notice the very striking and conspicuous phenomena of immense vertical cracks or joints, evidently due to the shrinkage of these marshy deposits during the progress of their desiccation. These cracks, by their intersection, form more or less rude approximations to quadrangular or hexagonal prismatic blocks. In some places they are from 10 to 15 feet across at the surface, and extend down probably to the bottom of the deposit, which reposes upon a stratum of hardpan, frequently 60 feet or more below. These cracks sometimes extend across the levees, thus originating serious crevasses and disastrous floodings.

The coefficient of contraction or shrinkage from loss of moisture in such deposits is simply enormous. Thus the finer sediments, due to the recent operations in hydraulic mining, in certain situations, form deposits from four to six feet deep over the older beds of sand along the banks of the Feather River (a tributary of the Sacramento). When this stratum of clay is subjected to the desiccating influence of the prolonged dry season, cracks are formed by shrinkage extending to the bed of sand, and so large that a man can walk on the sandy substratum between the vertical prismatic columns.

It seems to me that in these phenomena we have reproduced in *minimis* under our very eyes, the counterpart of what took place on a gigantic scale in the Salt Lake basin through the powerful desiccating influence of the arid climate which succeeded the Glacial epoch.

It is evident that when such cracks or joints become filled, by subaerial agencies, with sand and other materials, the subsequent lines of erosion must necessarily follow these channels

of rupture in the more compact subaqueous deposits of clay and marl.

I am indebted to my son, L. J. LeConte, for the facts above recorded. He had the opportunity of carefully observing the phenomena under consideration, in connection with the reconnaissance of the Sacramento valley, in relation to the improvement of the navigation of the river as well as our great engineering problem of the disposal of the debris resulting from hydraulic mining.

Of course every one is familiar with the cracks in mud or clay due to the shrinkage consequent upon drying; but, as far as I am aware, no one has called attention to the fact that they may be developed on so large a scale as to become an important factor in the physical geology of past ages.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Relation between the Optical and Thermal phenomena of Liquid Organic substances.*—Brühl has continued his researches on the connection between the physical properties of organic bodies and their chemical constitution, and in his last paper discusses the relation between the optical and the thermal phenomena observed in organic liquids. He finds: 1st, that progressive oxidation has the same influence on the optical as on the thermal properties; the refractive power, represented by $\frac{A-1}{d}$, diminishing as the amount of oxygen is increased, precisely as the heat of combination diminishes. Removal of hydrogen, or its replacement by oxygen produces the same effect; so that both the above physical values are greater for the hydrocarbons than for the alcohols, aldehydes, acids, etc., derived from them. The differences, however, diminish as the molecular weight increases, that between propyl-alcohol and propyl-aldehyde being smaller than between ethyl-alcohol and acetic aldehyde. 2d, halogenization has the same influence, both the refractive power and the heat of combination becoming smaller as the chlorine atoms increase. The constant for bromine is less than for chlorine, and for iodine it is still less. 3d, in the homologous series of alcohols, acids and ethers, both the optical and the thermal constants increase with increasing amounts of carbon and hydrogen, though the successive differences diminish as the molecular weight rises. 4th, the refractive power of isomeric bodies of equal saturating power is the same for all and is therefore independent of the atomic grouping, as the author had proved some time ago. The researches of Louguinine, Berthelot and others have shown the heat of combustion to be also the same for such bodies. 5th, in polymers, these phys-

ical constants are both smaller than those of the bodies producing them, and they diminish as the molecular weight increases; *i. e.*, the greater the number of the condensed molecules. 6th, isomeric bodies of unequal saturating power have different refractive powers; bodies in which doubly united atoms exist have a larger value of this constant than their isomers not having this union; and the value is larger when carbon atoms are doubly united than when carbon is thus joined to oxygen. Longuinine has proved the same to be true of the heat of combustion. Thus an unsaturated alcohol, as allyl alcohol, has a higher refractive power and combustion value, than the isomeric bodies propyl-aldehyde, or acetone. 7th, since if two bodies having the same molecular formula give different quantities of heat on combustion, they must contain different quantities of energy, it follows that the internal energy of bodies containing doubly combined atoms is greater than that of their isomers which have only singly united atoms. The energy of a body consists of the *vis viva* of its moving particles and of its interior work, the latter only, tending to diminish the forces uniting these particles and so to produce disaggregation. But the *vis viva* of isomeric bodies is equal; hence the difference of energy observed in these bodies represents a difference of internal work, the greater energy representing a looser aggregation of the atoms. Because greater energy is evolved in the case of doubly combined atoms, therefore it follows that the so-called double union of atoms shows not a more intimate, but on the contrary a weaker attraction, than single union; and hence the assumption of a stronger or denser union in unsaturated bodies, when their atoms are doubly combined, is directly the reverse of the fact. This conclusion is supported by Kopp's and by Buff's results showing that the volume of a body containing doubly combined atoms is greater than that of one containing only singly united ones; and also by the rule established by Kekulé that on oxidation of a body with doubly united atoms the molecule first breaks at the double union.—*Ber. Berl. Chem. Ges.*, xiv, 2533, Nov. 1881. G. F. B.

2. *Simple Dissociation Apparatus.*—Tommasi has described a simple apparatus which he called a *dissocioscope*, for showing the dissociation of ammoniacal salts. It consists of a tube of glass 20 to 25 centimeters long and 3 or 4 centimeters in diameter. By means of a platinum wire a slip of blue litmus paper, previously moistened with a solution of ammonium chloride, is suspended in the tube. The solution should be exactly neutral and be completely saturated. The paper is dipped in the solution, pressed for an instant between sheets of blotting paper and while still damp introduced into the tube. If now this tube be plunged into a cylinder containing boiling water, the ammonium salt is dissociated and the blue litmus paper becomes red. On placing it in cold water the dissociated ammonia and hydrogen chloride re-unite and the paper becomes blue again. This may be repeated any number of times at pleasure. Of course by using the bromide,

sulphate, or nitrate of ammonium the dissociation of these salts may be shown.—*Bull. Soc. Ch.*, II, xxxvi, 545, December, 1881.

G. F. B.

3. *On the Effect of Oxides on the Decomposition of Potassium Chlorate.*—Mills and Donald, continuing the researches upon the action of oxides upon salts begun by the first-named chemist, have studied the action of these oxides upon chlorates, a reaction observed by Dobereiner fifty years ago. The oxide employed was ferric oxide, purified by several precipitations, and ignited. The chlorate was several times recrystallized. The apparatus consisted of a shallow iron pot, within which was a low stage of porous tile, upon which was placed the bulb of a Schloesing's gas regulator, with the porcelain crucible in close proximity to it, covered by its lid. A thermometer bulb was placed near it, the iron pot was covered and heated with a Fletcher's burner. The air bath was first heated for a half-hour to the temperature of the experiment. The crucible with its mixture was inserted, and the heat continued for four hours. At the end of the time the crucible was removed, cooled in a desiccator and weighed. Five grams of chlorate were taken in each experiment, the quantity of oxide being gradually increased from a decigram to ten grams, the temperature being kept at about 195°. If the action of ferric oxide upon potassium chlorate be similar to that of an ordinary oxide upon an ordinary salt the numerical results should admit of representation under some form of the general equation $E = \frac{\alpha x y}{x_r + y_r}$ in which E is the chemical effect on oxygen expelled, x and y are respectively the masses of oxide and chlorate, x_r and y_r are the residues of these masses after action, and α is a factor of chemical effect, the number of chemical units of oxygen expelled per unit of oxide. The results suggest that the values of α are inversely proportional to the values of x. Calculation upon this hypothesis gave results closely agreeing with experiment. When x is very small, $\alpha = 3{\cdot}3028$, and $(Fe_2O_3)_3$ expels O_{10} or a unit of the oxide acts on rather more than a unit the chlorate. When x is very large, $\alpha = 0{\cdot}27240$, and the five grams of chlorate reaches the limit of 0·1775 gram oxygen expelled. Moreover as the mass of oxide increases its efficiency decreases. Inasmuch as in the action of ferric oxide on potassium carbonate, the factor of chemical effect, in the first stage, is inversely as the mass of oxide, the authors regard the entire course of the action of ferric oxide upon potassium chlorate as strictly analogous to the first stage of the action of the same oxide on potassium carbonate. This case of chemical change then presents nothing peculiar or abnormal and the name catalysis ceases to be applicable to the reaction now considered.—*J. Chem. Soc.*, xli, 18, Jan. 1882. G. F. B.

4. *On the Freezing point of Sulphuric acid of different Degrees of Concentration.*—Lunge has determined the point at which sulphuric acid of various strengths solidifies when exposed to cold. A freezing mixture of three parts ice and one of salt was used, in

which the thermometer sank to −20°. The first separation of crystals required prolonged cooling; but once effected, it takes place much easier and always at the same temperature. That temperature at which the first crystals appeared was called the freezing point. The fusing point could not be fixed with the same exactness. The thermometer was corrected, the specific gravity determined on an accurate balance and reduced to 15° by Schaeppi's tables. The Baumé degrees were calculated according to the rational aræometer, $d = \frac{144{\cdot}3}{144{\cdot}3 - n}$. The results obtained are given in the following tabular form:—

Sp. gr. at 15°.	Baumé.	Freezing point.	Fusing point.
1·671	58°	Liquid at −20°	----
1·691	59°	----	----
1·712	60·05°	----	----
1·727	60·75°	−7·5°	−7·5°
1·732	61·0°	−8·5°	−8·5°
1·749	61·8°	−0·2°	+4·5°
1·767	62·65°	+1·6°	+6·5°
1·790	63·75°	+4·5°	+8·0°
1·807	64·45°	−9·0°	−6·0°
1·822	65·15°	Liquid at −20°	----
1·842	66°	----	----

Ber. Berl. Chem. Ges., xiv, 2649, Dec. 1881. G. F. B.

5. *On the action of Water on Bismuthous iodide as illustrating Chemical change.*—Pattison Muir has suggested the action of water on bismuthous iodide as a lecture experiment well adapted for illustrating the influence of (*a*) time, (*b*) temperature and (*c*) mass, on a chemical change. Two forms of the experiment are given. In the first, a quantity of hydriodic acid—one part of strong acid to 100 of water—is divided into two equal parts. One is heated to boiling, the other remains cold; a small quantity of the cold solution is diluted with about three times its own bulk of water, a little of this is again diluted with about three or four times its volume of water. The four liquids are placed in beakers on white paper, and a few grains of solid bismuthous oxide is shaken into each. In the cold and strongest liquid brown BiI_3 is produced; in the hot liquid red BiOI; in the cold moderately dilute liquid, BiOI; and in the most dilute, there is little or no action. The second form of the experiment is performed by pouring a little of a solution of BiI_3 in strong hydrogen iodide into each of three beakers, the first of which contains 100 c.c. cold water, the second, the same at 90° to 100°, the third 500 c.c. cold water. Brown BiI_3 falls in the first, red crystalline BiOI in the second, and red BiOI but in smaller quantity, in the third. The brown BiI_3 passes into the red BiOI on standing; addition of strong HI reproduces brown BiI_3.—*J. Chem. Soc.*, xli, 4, Jan. 1882.

G. F. B.

6. *On the Splitting of Petroleum hydrocarbons at low Temperatures.*—Gustavson has observed that when in hydrocarbons obtained either from American or Caucasian petroleum, alumi-

num bromide is dissolved and hydrogen bromide gas is passed into the liquid, the whole heated in a paraffin bath, the mass separates into two layers, the composition of the lower one being always the same. It is a pretty thick liquid, of the consistence of aqueous glycerin, orange-red in color, not solidifying at -15°, permanent at $100^{\circ}-120^{\circ}$, but decomposing at higher temperatures into gaseous products, insoluble in the hydrocarbons from which it is formed, and in carbon disulphide, but miscible in all proportions with ethyl bromide. It has probably the formula $AlBr_3C_4H_8$. Besides this substance gaseous products are evolved, not condensible in a freezing mixture, and consisting of lower members of the series.—*Ber. Berl. Chem. Ges.*, xiv, 2619, Dec. 1881. G. F. B.

7. *On the Occurrence of Metaisocymene in Rosin oil.*—Of the six theoretically possible cymenes (propyl-toluenes) paranormalpropyltoluene has been obtained by Paterno and Spica, orthonormalpropyltoluene and metanormalpropyltoluene by Claus, and paraisopropyltoluene by Jacobsen. KELBE has now detected the existence of metaisopropyltoluene in the product of the dry distillation of rosin. From the lighter portions of the distillate, fractions were separated boiling from 108° to 115°, 160° to 170°, 170° to 180°, and 180° to 190°. In the first toluene was present and in the others cymene. To prepare the latter, the fractions from 160° to 190° were again fractionated, and the product treated for some hours with concentrated sulphuric acid on the water bath. Dilution with water and neutralization with barium carbonate gave the cymene-sulphate. But on saturating the acid with hydrogen chloride and heating in sealed tubes to 180°, cymene itself was obtained. From 15 kilograms of rosin-spirit, 800 grams of cymene were procured. On oxidation with chromic acid, isophthalic acid was obtained; thus proving the cymene to belong to the meta-series $C_6H_4\begin{cases}CH_3\,(1)\\C_3H_7\,(3)\end{cases}$. To determine the structure of the propyl group, isopropyl iodide was made to act on toluene in presence of aluminum chloride. A cymene was obtained identical with that obtained from the rosin-spirit. Thus proving the former to be metaisopropyltoluene $C_6H_4\begin{cases}CH_3\\CH\end{cases}\begin{cases}CH_3\,(1)\\CH_3\,(3)\end{cases}$. Several compounds of the new cymene are described.—*Liebig's Ann.*, ccx, 1, Oct., 1881. G. F. B.

8. *On the Aldehyde-nature of living Protoplasm.*—Starting from the fact observed by them, that living cells behave differently from dead ones, that living protoplasm has the power of reducing very dilute solutions of silver which dead protoplasm has not, LOEW and BOKORNY have concluded that living protoplasm is chemically of the nature of an aldehyde. Reinke suggested in it the presence of formic aldehyde, the authors have examined the distillate from algæ with a negative result. Their own view seems to them the more probable.—*Ber. Berl. Chem. Ges.*, xiv, 2441, Nov. 1881. G. F. B.

9. *On the Viscosity of Gases at High Exhaustions.*—In a paper read before the British Association in 1859, Maxwell presented the remarkable theoretical result that the coefficient of friction or the viscosity between layers of gas having different velocities of translation should be independent of the density of the gas. Previous experiments do not seem to confirm this view and Professor Crookes has lately investigated the subject, bringing to the study great experimental skill gained by long experience in obtaining and measuring high exhaustions. For the many refinements of the apparatus we must refer the reader to the original memoir. In its main feature the apparatus consisted of a torsion pendulum, composed of a plate of mica one-half of which was blackened, which was suspended by a long silk fiber in a tube filled with the gas whose viscosity at different exhaustions was to be examined. The movements of this torsion pendulum were observed by means of a beam of light which was reflected from a mirror placed upon the pendulum. Since the viscosity of the gases dampened the vibrations of this torsion apparatus (which was set in vibration by the radiometer effect on the semi-blackened plate of mica), a careful analysis of the decrements of the swings were necessary. Several curves illustrating the viscosity by means of this decrement in the swing are given; and a careful analysis on hydrodynamical principles by Professor G. G. Stokes is appended to Professor Crookes' paper. The following is a table of the results obtained by different observers.

	Graham.	Kundt and Warburg.	Maxwell.	Crookes.
Air	1·0000	1·0000	1·0000	1·0000
Oxygen	1·1099	"	"	1·1185
Nitrogen	0·971	"	"	0·9715
Carbonic anhydride	0·807	0·806	0·859	0·9208
Carbonic oxide	0·971	"	"	0·9715
Hydrogen	0·4855	0·488	0·5156	0·4439

Professor Crookes believes that his results are more accurate than those of previous observers. He has obtained a much lower viscosity in the case of hydrogen and believes that its accurate obedience to Maxwell's law is a proof of its purity, for any impurity arising from admixture of other gases impairs the results. The results uphold Maxwell's theory in general, and the more perfect the gas the nearer the agreement. Professor Stokes states in his discussion of Professor Crookes' results that the direct solution of the problem of the movement of a lamina like a mica plate in even a perfect fluid cannot be solved; but theory enables one to compare the viscosities in different media under certain conditions of similarity. Professor Stokes is accordingly led to the following law.

"If any pressure be taken in one gas and the pressures found in other gases for which the coefficients of viscosity are as the densities (pressures which have been defined as 'corresponding'), then if another system of pressures be taken proportional to the former the pressures in the new system will also correspond; and

consequently the ratio of the coefficients of viscosity of the different gases will be the same for the pressures in one such system as in another." He remarks "that this law is in accordance with Maxwell's law but does not by itself prove it." The constancy or tendency toward constancy is the viscosity as the rarefaction goes on, which is shown by Professor Crookes' experiments, is sufficient, in Professor Stokes' opinion, to establish Maxwell's law.—*Phil. Trans. of the Royal Society*, Part II, 1881, pp. 387–446.

J. T.

10. *Contributions to the Theory of Electro-magnetism.*—Two magnetic influences in different planes upon the particles of steel seemed to W. Siemens to require careful study and he has therefore experimented upon the magnetism of iron rings of different dimensions. These rings were simply hollow cylinders which were wound from end to end parallel to the axes of the cylinders, and magnetised by currents passing through these windings. At the same time the cylinders were surrounded by transverse windings. It was found that the magnetism produced in the ring was diminished by the simultaneous action of the windings which were perpendicular to the axis of the cylinder. This fact leads the author to theorize upon the arrangement of the polar particles and to modify previous theories. He calls attention to the advantages which the apparatus we have described possesses both to the investigator and to the practical electrician. In conclusion he experiments upon the shielding influence of iron covers or mantles to electro-magnets and arrives at some conclusions which appear to differ from the generally received opinions upon this influence. He promises further experiments upon this point.—*Ann. der Physik und Chemie*, No. 12, 1881, pp. 635–656.

J. T.

11. *Disintegration of Electrodes by Positive Electricity.*—Reitlinger and Wächter have carefully studied the formation of Lichtenberg's figures and conclude that the positive figures are due to conveyance of small material particles from the positive electrode and that the negative figures are due to the mechanical effect of the discharge of gases.—*Ann. der Physik und Chemie*, No. 12, 1881, pp. 591–610.

J. T.

12. *Upper Limit for the Kinetic Energy of Moved Electricity.*—Maxwell in his Electricity and Magnetism, vol. ii, describes an apparatus by which he hoped to detect the inertia of electricity if any such property existed. The results obtained by the apparatus however were negative. Hertz, without reference to the unsuccessful attempts of Maxwell, essays to detect this inertia by a different method. A current of electricity was conducted through a thin metallic plate, approximately of an elliptical shape. The battery current ran to the extremities of the major axis, and the terminals of a galvanometer were connected with the ends of the minor axis. The metallic plate was formed of silver deposited upon glass, and the needle of the galvanometer was brought to rest by scraping away a portion of the silver coating, at the side

of the plate and also by forming derived circuits between the ends of the major and minor axes. In fact the whole arrangement resembles that of a Wheatstone's bridge in which all the branches were confluent. This plate was then made to revolve about an axis perpendicular to the middle of the elliptical plate, and various ingenious arrangements were made to allow the terminals of the galvanometers and those of the battery to follow the motions of the plate. If the electrical current possessed inertia, a difference of potentials would be created by the revolution of the plate. This difference of potential being formed at the extremities of the minor axis of the ellipse would cause a current in the galvanometer whose terminals were connected with the ends of this axis. The various errors incident to this method of experimenting were closely examined and the results of the experiment appeared to the writer to warrant the assertion that he could wager 3480 to 1 that no movement of the needle of the galvanometer greater than one of his scale divisions could be ascribed to the inertness of the electricity. His calculation leads him to the formula $\mu = \frac{\varphi d}{4 J \omega}$ in which μ is the kinetic energy of a current of the magnetic density of 1 in a cubic millimeter of a silver conductor, φ the difference of potential between the ends of the minor axis, d the thickness of the metallic coating of the revolving plate, J the strength of the current passed through the plate, and ω the angular velocity of the plate. The value obtained for μ was $\mu = 0{\cdot}0000185$ mm.^{2} for one scale division which the author selected. He is led to believe that the value of μ would be much larger in liquids and that a positive result could be obtained with them if the difficulties of experimentation could be overcome.—*Ann. der Physik und Chemie*, No. 12, 1881, pp. 581–591. J. T.

13. *Electrical Units recommended by the Electrical Congress of* 1881.—(1.) The fundamental units are the centimeter, the gram and the second (C. G. S.). (2.) The volt and the ohm retain the present value, viz: 10^8 and 10^9. (3.) The resistance of one ohm will be represented by a column of quicksilver, of 1 millimeter square, in section, at 0° C. (4.) An international commission shall decide by new experiments what length this mercury column of 1 millimeter square section should have in order to represent the ohm. (5.) The current through one ohm with the tension of one volt is called an ampère. (6.) The quantity of electricity afforded by one ampère in one second is called a coulomb. (7.) A farad is defined to be that capacity by which one coulomb in one farad gives a volt.—*Ann. der Physik und Chemie*, No. 12, 1881, p. 708. J. T.

14. *Elementary Lessons in Electricity and Magnetism*; by Silvanus P. Thompson. 446 pp. 12mo. London, 1881 (Macmillan & Co.)—The beginner who wishes to make himself acquainted with the fundamental experiments of Electricity and Magnetism, and with the principles which have been deduced from them, will

find this little book an excellent guide. It is written from the modern standpoint, avoiding the use of old phraseology so likely to mislead the beginner, and explaining the not always simple ideas now accepted, in clear and intelligible form; the student who has mastered it will be in a position to go forward with more advanced treatises without having anything to unlearn. There is much fresh matter introduced into the text, but in this respect the figures are not quite all that the book deserves.

II. Geology.

1. *Glacial Erosion in Maine*; by Professor George H. Stone, of Colorado College. Proc. Portland Soc. Nat. Hist., Nov. 21, 1881.—Professor Stone treats in this paper of the composition and distribution and depth of the till in the State of Maine; of the effect of the ground moraine, where thick, in preventing abrasion; of the origin of the lake basins of Maine, whether by erosion or not; of the scarcity of organic matter in or beneath the till; of the probable rarity of sub-glacial streams; and, thence, of the small amount of glacial erosion in Maine. The average depth of the till is stated to be probably between 30 and 50 feet. The rarity of sub-glacial streams is sustained for the following reasons: the fact that no stratified deposits and only a moderate amount of glaciation have as yet been found in or beneath the ground moraine; that the direction of the valleys is not that of the glacial movement, and is sometimes transverse to it; that there were no peaks or ridges rising above the glacier to occasion the formation of crevasses; that the capping of ice over the hills was so thick that the ice may have moved independently of the hills and valleys beneath; and that the pressure of ice was so great that the lower part of the ice could hardly have been subjected to the strains necessary for making crevasses.

Another reason mentioned is that no pot-holes have been found except within a few miles of the sea. But no pot-holes could have been formed from the fall of water in crevasses while the ice was in motion. In borings by waters to make a cylindrical pot-hole, the tool has to work as truly about a center as in the use of a carpenter's augur. A motion of even a yard a century would elongate it.

2. *Glacial phenomena on the Delaware.*—Professor G. F. Wright, in a paper on the age of the Paleolith-bearing gravels in Trenton, New Jersey, states that these gravels rise to about 40 feet above present high-water level, (Trenton being at the head of tide-water); and that the Philadelphia brick-clay, which contains occasional bowlders, has a height of 150 feet above the river—a height "maintained with tolerable constancy up the Delaware as far as Easton, where the bed of the river is 157 feet above tide-level." This clay "rests unconformably upon the older gravel formations" In the Lehigh valley, at Bethlehem, a few miles above its junction with the Delaware valley,

this clay contains scratched pebbles, and overlies coarse gravel at a height of 180 feet above the river.

Professor Wright remarks that the area of the part of the Delaware valley that was covered by the ice was not far from 6,000 square miles, and that the thickness of the ice was probably about 1,500 feet; and, further, that, with the water at Trenton 150 feet deep, as the clay-beds would seem to indicate, the flooded river, flowing at a rate at least five miles an hour, would have carried off all the ice of the water-shed in 500 days or about 16 months. He hence concludes that, as this rate of discharge is highly improbable, there must have been "a depression of the region to the extent of 100 or more feet"; the era in which it took place was that of greatest depression during the Champlain period, when the ice was most rapidly melting away. The Trenton gravels are referred to a later part of this period.

3. *Jura-Trias of Southwestern Colorado;* by R. C. Hills. (Communicated).—The Jura-Trias period of Southwestern Colorado is divided into three epochs, not always clearly defined but well marked on the Rio De Las Animas, about three miles above Animas City, also on the Rio Dolores about 19 miles below Rico. The rocks of the lower epoch are exposed on the Uncompahgre, San Miguel, Dolores, La Plata, Animas and Florida. They consist of dark brown sandstone and conglomerate and brick-red sandstone and shale resting conformably upon the purplish beds of the Permo-Carboniferous.

The strata aggregate about 1,000 feet in thickness and are seemingly destitute of fossils.

The rocks of the middle epoch, absent on the Uncompahgre, begin on Leopard Creek, a few miles north of its junction with the San Miguel, and reach a maximum thickness of 250 feet on the Animas. On the upper San Miguel the lower portion of the beds is generally red laminated sandstone. Elsewhere they consist of light green micaceous sandstone and gray and drab slaty and massive sandstones interstratified with calcareous conglomerate which predominates in the upper part of the beds.

It varies in texture from a typical conglomerate to a rock in which the pebbles are so small, well-rounded and compactly cemented as to suggest, at first glance, an oölite. It is characteristic of the middle series and generally contains fragments of bone and teeth of saurians.

In the light-colored sandstone indistinct leaf impressions are, in some places, quite numerous. Tracks of a diminutive species of saurian occur in this rock on the San Miguel; although the saurian remains seem to be confined to the bands of conglomerate. Eleven or twelve determinable species of plants, one species of Ganoid and one Gastropod have been obtained from this division.

The upper member of the formation consists of about 250 to 300 feet of brick-red sandstone, absent on the Uncompahgre and San Miguel. Thus far it has yielded only one species of plant.

The rock overlying the formation on, and south of, the Dolores

is a pinkish-colored cross-grained massive sandstone. It underlies the gray sandstone of the Dakota group and is briefly alluded to by Holmes.* On the Uncompahgre and on the San Miguel, near the mouth of Leopard Creek, the Jura-trias is overlaid by a laminated sandstone of like color, having a band of bituminous limestone about 7 feet thick at the base. On the North Fork of the San Miguel the sandstone is generally gray and the limestone is from 20 to 40 feet thick.

This group is slightly unconformable with the Jura-trias, but, contrary to my statement in a previous communication on the subject,† it is conformable with the Cretaceous and more likely to be Lower Dakota than Jurassic.

III. Botany and Zoology.

1. *Notes on Gramineæ;* by George Bentham, F.R.S. Extract Jour. Linnean Society, vol. xix, p. 14–134.—A modest title to a most important essay, in which this veteran botanist sets forth the general arrangement he has made of the genera of Grasses, to appear systematically and fully in the ensuing part of the Genera Plantarum. It is the result of a critical study of the whole order, with the aid of unequalled collections, and under the light of unexampled experience. We shall not attempt an analysis of that which is itself an analysis of an extensive work, nor touch upon the history of the taxonomy of the order, which Mr. Bentham succinctly sketches, nor upon his view of the homology of the floral organs and their adjunets, which has been discussed in a separate paper a few years ago, of which due notice was taken in this Journal. Botanists do not need, and no others would be interested in, an abstract of these views and conclusions. In his reference to the morphology of the lodicules, Mr. Bentham hesitates whether to regard them as bractlets or as the representatives of perianth. His main objection to Hackel's conclusion—that they are bractlets—is their fore and aft position; but as this is a common position in the Monocotyledones, it seems rather to tell in favor of Hackel's view.

The arrangement of the genera makes some new associations and representations which may horrify old-fashioned agrostologists. In the two great divisions (which are those of R. Brown with a difference), and in the tribes (14 in number), much is made of articulation, which is of minor importance in most other orders. How the scheme will work remains to be seen. It is not probable that any living botanist could make a better one. The reader will probably be surprised to learn that, predominant as *Gramineæ* are in individuals, they are surpassed by the *Orchideæ* in the number of species. A. G.

2. *Flora Brasiliensis.*—The *Gramineæ* are continued by Doell in fasc. 83 (*Bambuseæ* and *Hordeaceæ*, the latter chiefly European species naturalized or cultivated in Brazil): fasc. 84, a large one, contains the greater part of the monospermous *Rubiaceæ* by Mül-

* Hayden's Report, 1875, page 266. † This Journal, vol. xix, 1880.

ler of Geneva. *Palicourea* and *Cephaelis* are reduced to *Psychotria*, of which there are 250 Brazilian species, although *Mapouria*, with 68 species, is kept distinct and made to include *Geophila*.

A. G.

3. *Diagnoses Plantarum novarum Asiaticarum:* IV. scripsit C. J. Maximowicz. Mel. Biol. Bull. Acad. Sci. St. Petersb. 1881. —It is pleasant to see more of the systematic work of Maximowicz, especially when it relates to Japan, as does some of it in the present fasciculus. *Hypericum pyramidatum* is identified with *H. Ascyron* and with the Japanese species; *H. Japonicum* of Japan, with *H. mutilum*; but it is remarked that the species in question can hardly be that of Linnæus, on account of a phrase in Mantissa, ii, 456. We certify that *it is* the Linnean plant, and also the Gronovian. And by tracing back the unfortunate addition in the Mantissa, made nearly twenty years later: "Folia tam arcte cauli appressa ut vix conspicua," it may be seen that Linnæus quoted Clayton's remark from a wrong species; and moreover that this is not *H. Sarothra*, for of it is said, "caule hirsuto." It is, indeed, *H. pilosum*, Walt. A synopsis is given of the E. Asian species of *Euonymus* and of *Celastrus*, and both are made feminine names, the former on the authority of Pliny, the latter on that of Theophrastus. A key is given to all the known species of *Chrysosplenium*, 39 in number; also of *Triosteum*, of which five are now known. *Lagotis* of Gærtner is taken up in place of *Gymnandra* of Pallas, and is said to be six years in priority. Two E. Asian species are added to *Koenigia*, and the genus is brought very near to *Polygonum*. Our *Ostrya Virginica* is identified in Japan.

A. G.

4. *On the Power possessed by Leaves of placing themselves at Right-Angles to the direction of Incident Light;* by Francis Darwin. Journal of the Linn. Soc., no. 112 (vol. xviii, p. 420–455), published June, 1881, read Dec. 16, 1880.—Taking up this subject where it was left by his father and himself in the work on "The Power of Movement in Plants," Mr. Francis Darwin, in this paper, records his investigations and experiments made with a well-devised modification of Sachs' Klinostat, with the view of determining whether Frank's or DeVries's explanation of the position which leaves normally assume with respect to the light is the more tenable. While the vertical position assumed by the growing plant's axis is attributed to geotropism and heliotropism, Frank attributes the position taken by leaves (with one face to the sky and the other to the ground) to transverse geotropism and transverse heliotropism. "An organ which grows transverse-geotropically, places itself horizontally. . . . In the same way a transversely heliotropic organ has an inherent tendency to place itself at right-angles to, instead of parallel [as does the stem] to the direction of incident light. It may be said that this is no explanation at all; and this is true in a certain sense. But there is no reason why it should be more unsatisfactory than the accepted explanation of the vertical growth of stems and roots, namely, that they

have an inherent power of growing in these directions." Indeed the one is just as satisfactory or unsatisfactory as the other. The terms "geotropism," "heliotropism," "apheliotropism" and the like, transverse or otherwise,—now a numerous brood,—are useful and not misleading when held to mean only that, in fact, a leaf "has an inherent tendency to be horizontal" or "to place itself at right-angles to the direction of incident light" and "the hypocotyl of a seedling has an inherent tendency to grow vertically upwards." These technical terms are unsatisfactory when they are supposed to carry more explanation than the simple and untechnical statement does. But do leaves take their position in virtue of an inherent tendency? This is substantially denied by DeVries, or at least he maintains that the assumption is needless, for that it may be a result of an antagonism between positive and negative heliotropic and geotropic forces, or between these and what he calls *epinasty* and *hyponasty*. These new technical terms are simple in meaning. An organ, such as a leaf, is epinastic when the upper half grows in length more than the lower, and the effect is convexity above and concavity below, or downward curvature: it is hyponastic when the reverse takes place. And the suggestion is, that the horizontal position of a leaf under zenith illumination may be due simply to an equilibrium between two or more of these opposing forces. It is unnecessary to enter into particulars of how this obviously might produce the effect: for the result of Mr. Francis Darwin's experiments is a clear disproof of DeVries' suggestion. In the "fundamental experiment: . . if a plant whose leaves have the power of placing themselves at right-angles to incident light is growing normally in the open air and lighted from above, its leaves will be horizontal. Let the plant be now made to rotate on a klinostat [so slowly that no centrifugal effect will be produced, but rapidly enough to destroy all geotropic action] so that the axis of rotation coincides with the axis of the plant. And let the direction of the incident rays of light be parallel to the axis of rotation, so that the morphologically upper side of the leaves is illuminated by rays striking them at right-angles, just as they were when the plant grew on the ground. Then, if the normal horizontal position is the result of a balance between geotropism (positive or negative) and any other force—epinasty, hyponasty, positive or negative heliotropism,—it is clear that, geotropism being destroyed by the rotation, the balance cannot be maintained." The experiments, varied in many ways, and with arrangements to eliminate epinastic and hyponastic tendencies, plainly bring out the conclusion "that the power which leaves have of placing themselves at right-angles to the incident light is due to a specialized sensitiveness to light, which is able to regulate or govern the action of other external forces, such as gravitation, or of internal forces, such as epinasty." A. G.

5. *The Botanical Collector's Handbook.* By W. Whitman Bailey, Olney Professor of Nat. Hist. (Botany) in Brown University, R. I. Salem: Bates, 1881. pp. 139, 12mo.—This is

No. III of The Naturalist's Handy Series, and handy it is. It patiently and particularly imparts to the incipient botanist the information which he needs, and which he will not find much of in his text-books and manuals,—how to herborize, with full particulars and, indeed, figures, of all the implements he can possibly require; how to prepare his specimens for the herbarium, and to arrange and manage the same; what books are most needed; what and where the principal public herbaria of the United States are (the Philadelphia herbaria omitted!); and there are special chapters on the management of the Cryptogamia, in which the author has been much assisted by specialists. The veteran collector, Charles Wright, contributes the article on the preparation of *Cactaceæ*, and much else in the way of herborization is from his large experience. The book appears to supply a recognized and increasing want. A. G.

6. *The Greenland Flora.*—A year hence the classical *Flora Danica* will be terminated by the completion of the seventeenth volume. The work will contain figures of 4,000 species of plants, of Scandinavia, including Greenland and Iceland. It has been published wholly at the expense of the King of Denmark, and is a right royal work indeed. At its completion the plates (in folio) which relate to Greenland plants, and which illustrate its whole flora, are to be separately issued, with a brief letter-press, under the title of *Icones Flora Groenlandicæ*. As this flora is in one sense American, and as the copies of the whole Flora Danica in the United States are and must be very few, we take pleasure in announcing this illustrated Greenland Flora to American botanists. Some of them will wish to possess it. The price of uncolored copies is fixed at 56 francs, of the colored at 236 francs. It should be added that, as the impression is strictly limited, application should be made very promptly. The editor, Professor Joh. Lange, Copenhagen, informs us that he will himself receive subscriptions, up to the first of May next. A. G.

7. *A Memoir on the Echinodermata of the Arctic Sea to the west of Greenland;* by P. Martin Duncan and W. Percy Sladen. Large 4to, 82 pp., six lithographic plates. London, John Van Voorst, 1881.—This work is of special importance to American naturalists interested in this group of animals, for a large proportion of the species treated are found upon the New England coast. All the species are described in detail and nearly all of them are well illustrated. The whole number of species is thirty. Seven are holothurians;* of these all, except, perhaps, *Oreula Barthii*, are New England species, and the latter occurs on George's Bank and off Nova Scotia. Eight of the ten starfishes occur on the New England coast, the ninth (*Asteracanthion* [*Asterias*] *polare*) occurs in the Gulf of St. Lawrence and off Nova Scotia, and only one is, so far as known, peculiar to the

* The authors have included, erroneously, I believe, as the young of *Cucumaria frondosa*, the form that is regarded by me, and many others, as a distinct species (*Pentacta minuta*).

Greenland seas (*Pedicellaster palæocrystallus* Sladen); but it is possible that a *Pedicellaster* dredged in the Gulf of St. Lawrence several years ago, by Mr. Whiteaves, who sent me a specimen, in poor condition, for examination, is identical. Of the nine ophiurans, including *Astrophyton Agassizii*, five are common New England species; *Ophioglypha Stuvitzii* occurs on the Grand Banks and in the Gulf of St. Lawrence (Whiteaves); *Amphiura Holbœlli* occurs in the Gulf of St. Lawrence; while *Ophiocten sericeum* (Forbes) and *Ophiopleura arctica* Duncan appear to be confined to the arctic waters. The latter is, however, closely related to *Ophioglypha* (*Ophiopleura*) *aurantiaca* V.,* described in the last number of this Journal, which has been taken by us, several times, off the south coast of New England. This genus, therefore, can no longer be regarded as peculiar to the arctic region. Of the three crinoids one (*Antedon Eschrichtii*) is recognized as inhabiting the New England region, for it is common on the Banks off Nova Scotia, and especially off Cape Sable, N. S.; *A. celtica* Norm. and *A. prolixa* Sladen are not known from our coast, unless the latter be the same as some of the forms that I have hitherto called *A. Sarsii*, our commonest species, which it certainly closely resembles, in some respects.

In discussing the geographical distribution of the species the authors recognize the large number of species that extend southward along the North American coast to Nova Scotia, Maine, etc., but in a number of cases the range on our coast, as determined by our later researches, is more southern than they give. Thus, *Cucumaria* [*Pentacta*] *frondosa*, *Psolus* [*Lophothuria*] *Fabricii*, *Ctenodiscus corniculatus* [=*crispatus*], *Ophiacantha spinulosa*, *Astrophyton Agassizii* have all occurred south of Cape Cod; while *Stichaster albulus*, *Cribrella oculata*, *Ophioglypha Sarsii*, *Ophiopholis bellis* [=*aculeata*] are common as far south, at least, as the region off Chesapeake Bay, and very likely will be found to go much farther south, along the Atlantic slope, in moderate depths. Finally, we may add that at least 25 of the 30 species (or about 83 per cent) extend as far south as the Gulf of St. Lawrence and Nova Scotia; 22 extend to the Gulf of Maine; 11 pass to the south of Cape Cod; 5 extend to the region off Chesapeake Bay.

A. E. V.

8. *Discovery of a rare fresh-water shell* (*Gundlachia*) *in western New York;* by JOHN M. COOKE.—In the summer of 1880 I found several individuals of this genus in the waters of a "Sucker Brook," which flows through the village of Canandaigua, N. Y. The species does not agree either with *G. Californica*, nor *G. Meekiana*, our two American species. Four have been described by Pfeiffer and Bourguignat from the West Indies. The specimens which I found were in a pool formed in the summer shrinkage of the stream. In the last season I was unable to find them

* This species was described (p. 141) as an *Ophioglypha*, but it is evidently congeneric with *Ophiopleura arctica*, from which it differs in the smaller size of the under arm-plates, upper arm-spines larger and flattened, differently shaped mouth-shields, etc.

again. They were associated with *Ancylus* and other common forms, and it is in the hope of finding them in the future, in sufficient quantity to enable me to make a study of the animal and its life history, that I defer any description of the shell, incomplete as it would necessarily be.

In examining a Quaternary fresh-water shell-marl from St. Helena Island, off the coast of South Carolina, I have found a *Gundlachia* among the other shells —*Ancylus*, *Planorbis*, *Succinea*, *Pisidium*, etc., but always too immature to be identified with any species existing either on the Continent or in the West Indies. This is Mr. Tryon's opinion, as well as this, that the species of the associated genera mentioned are several of them both West Indian and Continental.

It is interesting, therefore, to find along with the *Gundlachia*, a species (*Pupa* (*Vertigo*) *heradon*) described by C. B. Adams from Jamaica, and not as yet identified on the Continent. It was in this shell-marl that almost the entire skeleton of a *Mastodon* was found, about fifteen years ago, by Capt. C. S. Boutelle, of the U. S. Coast Survey. J. M. C.

IV. Miscellaneous Scientific Intelligence.

1. *Minor Planets.*—Since the list of minor planets in volume xviii was published, there have been added *thirteen* to the number.

210	Isabella,	discovered by	Palisa,	Nov	12, 1879
211	Isolda,	"	Palisa,	Dec.	11, 1879
212	-------	"	Palisa,	Feb.	6, 1880
213	Lilæa,	"	Peters,	Feb.	17, 1880
214	Aschera,	"	Palisa,	Mar.	1, 1880
215	Oenone,	"	Knorre,	Apr.	7, 1880
216	-------	"	Palisa,	Apr.	10, 1880
217	-------	"	Coggia,	Aug.	30, 1880
218	-------	"	Palisa,	Sept.	4, 1880
219	-------	"	Palisa,	Sept.	30, 1880
220	-------	"	Palisa,	Feb.	23, 1881
221	-------	"	Palisa,	Jan.	18, 1882
222	-------	"	Palisa,	Feb.	9, 1882

The following names have been given to planets previously discovered: (204) *Kallisto;* (205) *Martha;* (207) *Hedda;* (208) *Lacrimosa.* H. A. N.

2. *Hailstorms.* — A letter to the editors from Mr. J. A. B. Oliver (Athenæum, Glasgow, Scotland), states that he is preparing a memoir for the Meteorological Society on "Hailstorms." He asks any persons, who have opportunities of observing hailstorms, to furnish him with particulars of them. The points to be particularly observed are as follows:

1. *Date*, and hour of the day. 2. *Area of the storm*, if it assume the tornado form, give (*a*) length of the course, (*b*) breadth. (*c*) direction of motion. (*d*) rate of progression. 3. *Physical features* of the locality, (*a*) elevation, (*b*) mountains and plateaus. (*c*) rivers and valleys. (*d*) forests. &c. 4. *Temperature*, (*a*) before the storm. (*b*) after the storm, and if possible to be observed, (*c*) changes during the storm. 5. *Barometrical readings* frequently taken during time of hailstorms. 6. *Wind*, (*a*) direction near the earth's surface, (*b*) direction in the higher regions

as indicated by the cloud motion, (*c*) force. 7. *Preceded or followed by rain.* 8. *Aspect of the clouds.* Note if there be any appearance of two separate strata at different elevations. 9. *Electrical phenomena*, should there be lightning, note the relation between the discharges and the fall of the hail—whether the lightning precede the hail, or *vice versa*. 10. *Duration* of the storm at one spot. 11. *Sound.* Note if a peculiar noise precede the descent of the hail. 12. *Conformation and size of the hailstones.* 13. Weather before and after the storm.

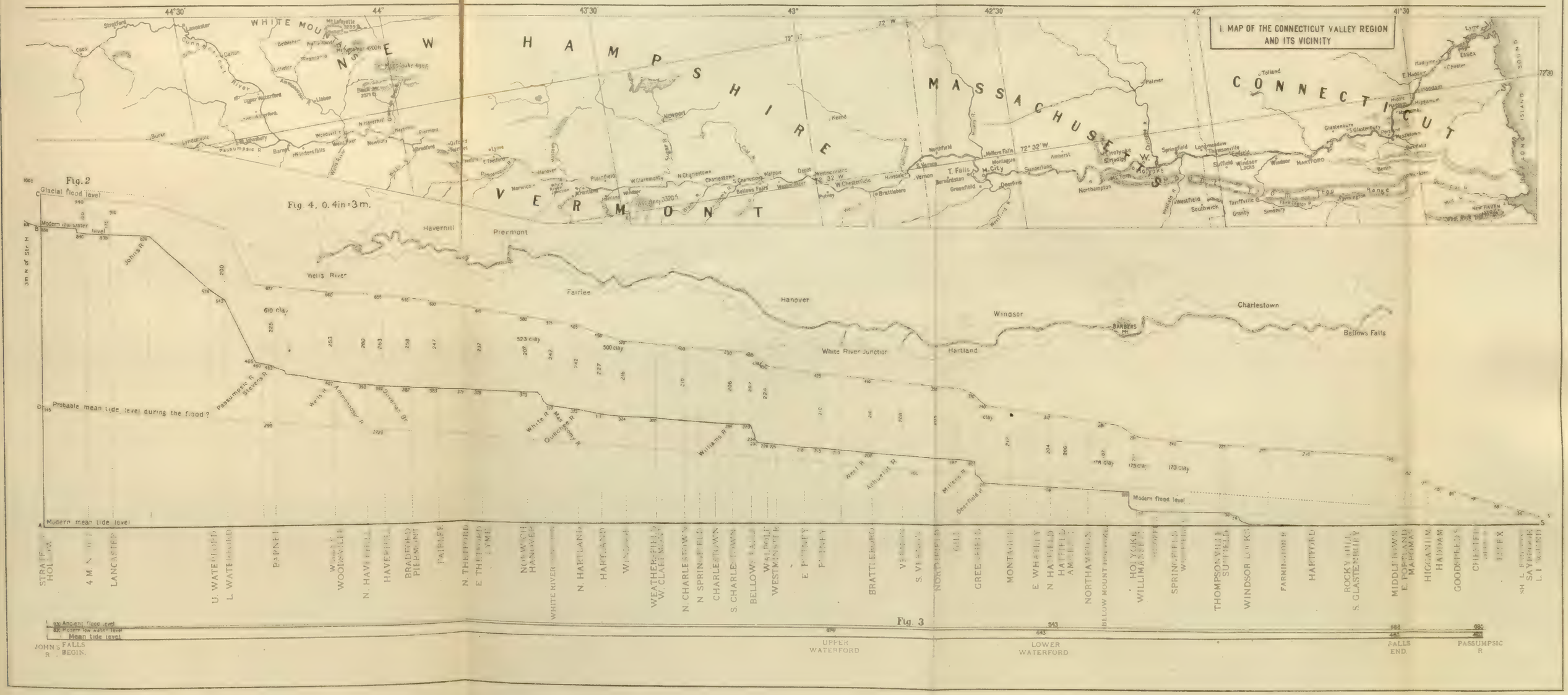
3. *Schott's Tables and Results of the Precipitation in Rain and Snow in the United States and some adjacent parts of North and South America*, published by the Smithsonian Institution. A new edition (second) of this very valuable memoir was issued in May last by the Smithsonian Institution under the direction of Mr. C. A. Schott. It makes now a quarto volume of 248 pages, with 10 plates. In the first edition the records were tabulated down to the close of 1866; in the new, to the end of 1874, and to some extent to the end of 1876. The five rain charts of this edition were constructed between April and June, 1880, and are made of the same size as the temperature charts of the Smithsonian Memoirs by Schott. The explanatory notes and deductions have been written anew, and various other changes have been introduced.

4. *Boston City Water: Report on a peculiar condition of the Water in November*, 1881; by Prof. Ira Remsen, with notes by A. Hyatt and W. G. Farlow.—The "peculiar condition" is one observed in the waters supplied to cities at certain seasons, in which the taste is a "cucumber taste" or a "fish-oil" taste. Prof. Remsen found in his observations that such waters contained more "albuminoid ammonia" than those not having the taste, and by this observation ascertained the particular ponds that sent to Boston the offensive waters. He afterward examined the mud of the bottom of Farm Pond, without positive results; detected green masses of the size of pin-heads, which rose to the surface, and were recognized as plants of the *Nostoc* family by Prof. W. G. Farlow, but which did not have the smell; obtained from the screens, through which the water passes at the effluent of the gate-house of the pond, among dead leaves, etc. "some curious masses, green to brown in color," which gave off the disagreeable "cucumber odor," much intensified; some of the pieces, 4 or 5 inches in length, though most not over an inch, and so reached the root of the matter. Prof. Farlow recognized the material as a fresh-water sponge, and Prof. Alpheus Hyatt as the common species *Spongilla fluviatilis*.

5. *The Lalande Astronomical Prize* was awarded by the Academy of Sciences of Paris, at its recent annual meeting, to Professor Swift, of Rochester, N. Y.

6. *La Lumière Électrique.*—This excellent electrical journal, since the beginning of the year, appears but once instead of twice weekly; at the same time the size of the numbers has been increased from 32 to 48 columns.

7. *Cosmos-Les-Mondes.*—With the beginning of 1882 the well-known review, edited by the Abbé Moigno, commences volume I of a *third series*.



2. SECTION OF THE CONNECTICUT RIVER DURING THE FLOOD FROM THE MELTING GLACIER

RHAMPHORHYNCHUS PHYLLURUS, Marsh.

E. Gerard, lith.

THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

Art. XXIV.—*The Wings of Pterodactyles*: (with Plate III). by Professor O. C. Marsh.

The first Pterosaurians discovered were recognized as flying animals, but were thought to be bats. As soon as their general structure became known, they were classed with the Reptiles, although it was considered possible that their power of flight was due to feathers. Later, their bones were mistaken for those of Birds by various experienced anatomists, and others regarded them as sharing important characters with that group. Some anatomists, however, believed that the fore limbs of Pterodactyles were used for swimming, rather than for flight, and this view has found supporters within the present decade. A single fortunate discovery, made a few years since, has done much to settle the question as to the wings of Pterodactyles, as well as their mode of flight, and it is the aim of the present article to place on record some of the more important facts thus brought to light.

The specimen to be described was found in 1873, near Eichstädt, Bavaria, in the same lithographic slates that have yielded *Archæopteryx*, *Compsognathus*, and so many other Jurassic fossils known to fame. This specimen, which represents a new species of the genus *Rhamphorhynchus*, is in a remarkable state of preservation. The bones of the skeleton are nearly all in position, and those of both wings show very perfect impressions of *volant membranes* still attached to them. Moreover, the extremity of the long tail supported a separate vertical membrane, which was evidently used as a rudder in flight.

These peculiar features are well shown in Plate III, which represents the fossil in the natural size.

The discovery of this unique specimen naturally attracted much attention at the time, and many efforts were made to secure it for European museums. The writer was then at work on the toothless Pterodactyles which he had recently found in the Cretaceous of Kansas, and believing the present specimen important for his investigations, sent a message by cable to a friend in Germany, and purchased it for the museum of Yale College, where it is now deposited.

The Wing Membranes.

A careful examination of this fossil shows that the patagium of the wings was a thin smooth membrane, very similar to that of modern bats. As the wings were partially folded at the time of entombment, the volant membranes were naturally contracted into folds, and the surface was also marked by delicate striæ. At first sight, these striæ might readily be mistaken for a thin coating of hair, but on closer investigation they are seen to be minute wrinkles in the surface of the membranes, the under side of which is exposed. The wing membranes appear to have been attached in front along the entire length of the arm, and out to the end of the elongated wing finger. From this point, the outer margin curved inward and backward, to the hind foot.

The membrane evidently extended from the hind foot to near the base of the tail, but the exact outline of this portion cannot at present be determined. It was probably not far from the position assigned it in the restoration attempted in the cut given below, figure 2. The attachment of the inner margin of the membrane to the body was doubtless similar to that seen in bats and flying squirrels.

In front of the arm, there was likewise a fold of the skin extending probably from near the shoulder to the wrist, as indicated in figure 2. This fold enclosed a peculiar bone (pteroid), the nature and function of which will be discussed below in considering the osteology of this part of the skeleton.

The Caudal Membrane.

The greater portion of the tail of this specimen was free, and without volant attachments. The distal extremity, however, including the last sixteen short vertebræ, supported a vertical membrane, which is shown in Plate III, and also in the woodcut, figure 1. This peculiar caudal appendage was of somewhat greater thickness than the patagial membrane of the wings. It was rhomboid in outline, and its upper and lower

portions were slightly unequal in form and size. The upper part was kept in position by a series of spines, sent off one from near the middle of each vertebral centrum, and thus clearly representing neural spines. The lower half also was strengthened by similar spines, which descended from near the junction of the vertebræ, and hence were homologous with chevron bones. These spines were cartilaginous, and flexible, but sufficiently firm in texture to keep the membrane in an upright position.

1.

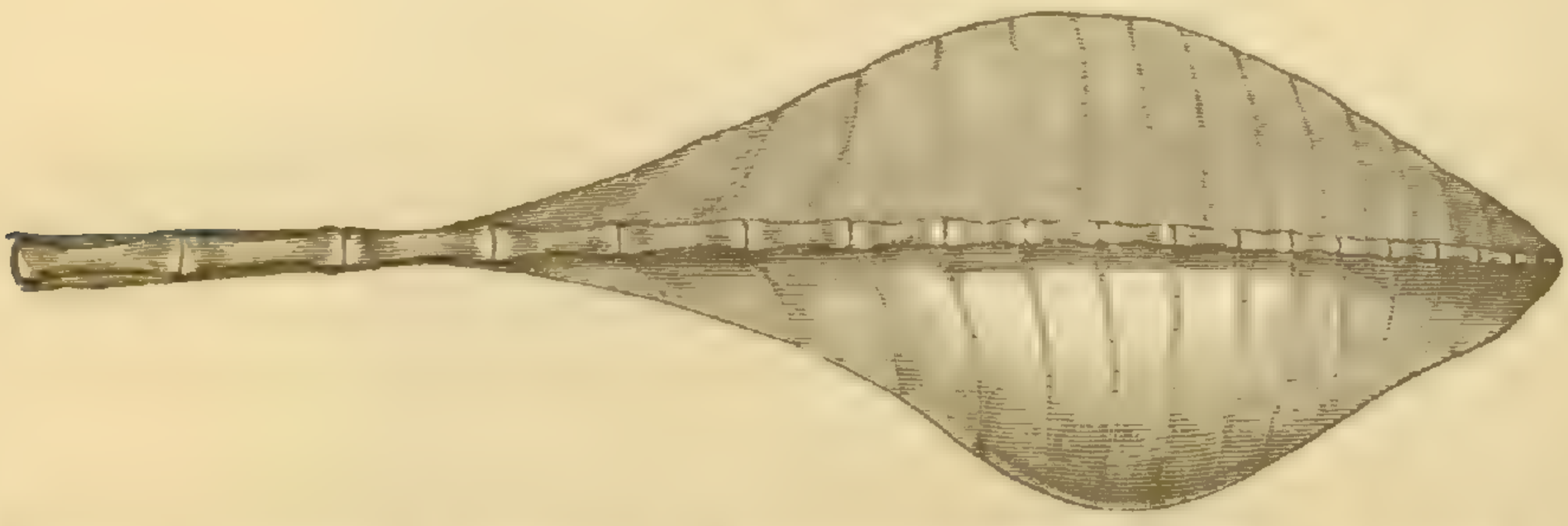


FIGURE 1.—Caudal extremity of *Rhamphorhynchus phyllurus*, Marsh; natural size. Seen from the left side.

THE SCAPULAR ARCH.

The osteology of the scapular arch and wings of Pterodactyles involves many interesting points, some of which have been discussed by anatomists from Cuvier to those of the present day, but with little agreement of opinion. The cause of this diversity of opinion is mainly due to the fact that the specimens examined have been either too small or too imperfect for accurate determination of their more obscure parts. Fortunately, the museum of Yale College has among its specimens of Cretaceous Pterodactyles (some 600 in all), quite a number with the scapular arch and wing-bones nearly perfect, and in position. These specimens were nearly all of gigantic size, having in life a spread of wings from fifteen to twenty feet. They were also destitute of teeth, and belong to the order *Pteranodontia*. Probably their great size induced special modifications of the scapular arch, which is here far more complicated than in any other members of the group.

In the Jurassic Pterodactyles, the scapula is usually bird-like in general form and proportions, the upper or distal extremity being free and compressed. This is the case in the specimen here described. The scapula and coracoid may be coössified, as in the present fossil, or remain more or less separate. No clavicles have yet been found. The sternum here shows no distinct facets for sternal ribs.

In the Cretaceous genus *Pteranodon*, and probably also in some of the other gigantic forms from deposits of this age, the

scapula and coracoid were not only solidly united, but the pectoral arch was further strengthened (1) by the ankylosis of several vertebræ, and (2) by the robust scapulæ articulating on opposite sides of the common neural spine of these vertebræ. This is virtually a repetition of the pelvic arch, on a much larger scale. The sternum also is massive, and shows well marked facets for the sternal ribs. This peculiar method of strengthening the scapular arch has not been observed in any other vertebrates.

The Wing Bones.

The three principal bones of the arm (humerus, radius, and ulna), present such similar characters in all Pterodactyles, that they need not be considered here in detail. It is important, however, to bear in mind that the ulna, although but little larger than the radius, contributes the greater share of direct support to the enormously developed wing finger, which is on the outer or ulnar side of the hand. As this position has been a question of discussion among anatomists, it may be well to state, that the writer bases his opinion upon this point on the results of an examination of the best preserved specimens in European museums, as well as nearly all known in this country. The latter specimens settle the question beyond doubt.

The views expressed by anatomists in regard to the bones of the wrist and hand of Pterodactyles are almost as various as the specimens investigated. Some of the restorations of these parts that have been published from time to time, and repeated in text books, have done much to propagate errors, and little to clear away the serious difficulties in the case. The main facts in regard to the carpus now known may be briefly stated as follows:

In all Pterodactyles, there are two principal carpal bones, placed one above the other. These sometimes show indications of being composite, but their constituent parts have not been satisfactorily determined. On the inner side of the wrist, articulating with the distal carpal, there is a smaller bone which has been called the "lateral carpal." In addition to these three bones, some American Pterodactyles have on the inner side three ossicles, which may be sesamoid bones. Two of these have been seen in a few Jurassic forms in Europe. Beside these, there is often found on the radial side of the wrist, and sometimes attached to it, a long, slender styloid bone, having a rounded articular head on its carpal extremity. This is the so-called "pteroid bone," to which allusion has already been made above. This bone and the "lateral carpal" which supports it are usually placed by anatomists on

the outer or ulnar side, but American specimens prove conclusively that they belong on the radial side.

The nature of the so-called pteroid bone has been much discussed, but without a satisfactory conclusion. After a careful study of many specimens, the writer is disposed to regard it, not as an ossified tendon, but as a part of the first digit, or thumb, which is usually considered wanting in Pterodactyles. According to this view, the "lateral carpal" would probably be the metacarpal of the same digit. In favor of this interpretation, it may be said—

(1.) That the position and structure of this appendage of the carpus correspond closely with that of the first digit in some other reptiles, for example, *Iguanodon*.

(2.) The "lateral carpal" unites both with the distal carpal and with the "pteroid" by very free, well-defined articulations.

(3.) In American specimens, the "lateral carpal" stands nearly at right angles to the wrist, and the "pteroid" is much bent near its articular end.

(4.) In no Pterodactyle known is there any remnant of a digit outside the wing finger, where the membrane might be expected to retain it.

(5.) This view would make the wing finger the fifth digit, the same to which the membrane is attached in the hind foot.

Perhaps the strongest objection against this interpretation is the number of phalanges in the respective digits of the hand. These, however, are not constant in the known Pterodactyles, and they vary much in other reptiles which have the digits highly specialized. This subject will be more fully discussed by the writer elsewhere.

According to the above interpretation, there are five digits in the hand of Pterodactyles, although not the five often given in restorations. The first digit, the elements of which have been considered, undoubtedly supported a membrane in front of the arm. The second, third, and fourth are small, and armed with claws. The large wing finger is the fifth, corresponding to the little finger of the human hand.

The metacarpal bones are much elongated in the Pterodactyles with short tails, and quite short in those, like the present specimen, that have the tail long. The metacarpal of the wing finger is always large, and robust, while those of the claw-bearing digits are usually quite slender. In *Pteranodon*, the second metacarpal is a slender thread of bone, throughout most of the length, while the third and fourth are attenuated splint bones, incomplete above.

The phalanges of the three middle digits are quite short, and the terminal ones supported sharp claws. The wing finger has four greatly elongated phalanges, the last being a styloid bone,

without a claw. This digit is well shown in the right wing represented in Plate III, and also in the restoration, given below, in figure 2.

In the restoration here attempted, the writer has endeavored to reproduce (1) the parts actually present or clearly indicated in the specimen described, and (2) those which the former seemed to require to complete the outward form in life. The

2.

FIGURE 2.—Restoration of *Rhamphorhynchus phyllurus*, Marsh; one seventh natural size.

membrane at the base of the tail may have been somewhat less in extent, and the fold of the skin above the fore-arm either more or less developed than here represented, but the facts now known render the outlines here given more than probable. The hands are represented with the palms forward.

The present species appears to be most nearly related to *Rhamphorhynchus Gemmingi*, von Meyer, from the same geological horizon, and near the same locality. That it is quite distinct, however, is shown, aside from the difference in size, by the complete ankylosis of the scapula and coracoid, and by the fifth digit of the hind foot being well developed, and having three phalanges. In the name *Rhamphorhynchus phyllurus*, here proposed for the species, the latter designation refers to the leaf-shaped caudal appendage, which appears to be one of its most characteristic features.

For the long delay in the description of this important European specimen, the writer can only plead *l'embarras des richesses* nearer home.

Yale College, New Haven, March 14, 1882.

EXPLANATION OF PLATE III.

Rhamphorhynchus phyllurus, Marsh. Natural size.

The animal lies upon the back, and the under surfaces of the wing membranes are exposed. The caudal membrane is seen from the left side.

Art. XXV.—*On Sandstones having the grains in part Quartz Crystals;* by Rev. A. A. Young, of New Lisbon, Wisconsin.

In the Potsdam sandstone of the vicinity of New Lisbon, Wisconsin, and the St. Peters sandstone of Grant County in the same State, I have found many of the quartz grains to be true quartz crystals with polished faces. On mounting some of the grains in balsam, and then examining them with the microscope, many were found to have well-defined nuclei of varying sizes, proving that the crystalline form was produced by the finishing out of original irregular grains of the sand-bed, which are now the kernels of the crystals, thus according with observations by Mr. Sorby, as described in his Presidential address, of 1880, before the Geological Society. Some of the kernels are quite translucent, others nearly opaque, and occasionally one has a needle of rutile (?) which does not extend beyond.

Art. XXVI.—*Notes on American Earthquakes:* No. 11; by Professor C. G. Rockwood, Jr., Ph.D., Princeton, N. J.

This article embodies such information as the author has obtained in regard to the earthquakes which occurred upon the American continent and adjacent islands during the year 1881, with notice of some earlier shocks not previously reported. Items which depend upon single sources of information have their source indicated, and if regarded as doubtful are printed in smaller type.

For assistance in collecting information the author is indebted to J. M. Batchelder, Esq., of Boston, to President J. W. Dawson, of Montreal, and to the Superintendent of the Meteorological Service at Toronto. The Monthly Weather Review of the U. S. Signal Service has also furnished valuable information.

1880.

Sept. 28.—6 P. M. Three heavy shocks on the island of Ukamok, Alaska (55° 48′ N., 155° 34′ W.); the first in north–south direction, the others west–east; 9 P. M., severe shock from W. to E. 29th, 3 A. M. and 1 P. M., heavy shocks from W. to E. "From the commencement of this phenomena, Sept. 28th, until its subsidence, Oct. 16th, there was an uninterrupted trembling motion of the earth, interspersed with heavy, subterranean, rumbling sounds. During a short trip over a portion of the island, on Sept. 29th, deep fissures, with a width of from fifteen to twenty inches were found to be very numerous." The above is reported by Mr. A. Newlander, at that time a resident of the island.—*U. S. Weath. Rev.*

Oct. 26 to 29. In regard to the earthquake shocks of these dates in Alaska (already reported, vol. xxi, p. 201), the following details of separate shocks are given by the Sitka correspondent of an Oregon paper, as are also the two succeeding items in November: Oct. 26th, 1.20 P. M., very severe shock, east–west; 2.14 P. M. and 8.46 P. M., slight shocks; 27th, 5.35 A. M., two short and sharp shocks, east–west; 9.15 P. M., sharp shock, S.W. to N.E.; 11.04 P. M. and 11.45 P. M., slight shocks, east–west. 29th, 1.05 A. M., a shock; 6.38 A. M., a sharp shock, S.E. to N.W., with rumbling noise; 11.58 P. M., three shocks, N.E. to S.W.—*U. S. Weath. Rev.*

Nov. 13.—5.28 A. M. A shock at Sitka.—*U. S. Weath. Rev.*

Nov. 14.—5.50 A. M. Two shocks at Sitka, N.E. to S.W.—*U. S. Weath. Rev.*

1881.

Jan. 1.—6.55 P. M. A shock at Red Bluff, Cal.; vibration, north–south.—*U. S. Weath. Rev.*

Jan. 5 to 7. At Bainbridge Island, W. T. (47° 42′ N., 122° 31′ W.); slight shocks at 10.56 P. M. of 5th; at 4.20 P. M. of 6th, and at 10.15 P. M. of 7th.—*U. S. Weath. Rev.*

Jan. 6.—6.25 P. M. A shock at Red Bluff, Cal.; vibrations, N.W. to S.E.—*U. S. Weath. Rev.*

Jan. 7.—6.15 A. M. Slight shock at Campo, Cal.—*U. S. Weath. Rev.*

Jan. 16.—11 P. M. Slight shock at Bainbridge Island, W. T.—*U. S. Weath. Rev.*

Jan. 20.—9.40 P. M. The shock felt in the vicinity of Bath and Brunswick, Me. (vol. xxi, p. 202), was accompanied by a rumbling noise.

Jan. 24. Three shocks felt at San Francisco and Oakland, Cal. At the former place the times were stated as 8.54 P. M., 9.15 P. M., and 11.15 P. M., and the direction N.W. to S.E. At Oakland the first and second shocks were accompanied by a low rumbling, and the direction is stated to have been S.W. to N.E.

Jan. 30.—9.45 P. M. A slight shock at Bainbridge Island, W. T.—*U. S. Weath. Rev.*

Feb. 1. At Visalia, Cal., at 4.11 P. M., three shocks lasting altogether about two seconds, and at 9.53 P. M. two more shocks. Motion, S.E. to N.W.—*U. S. Weath. Rev.*

Feb. 2.—A slight shock from north to south at Salinas City, Cal.—*U. S. Weath. Rev.*

Feb. 2.—About 4 A. M. a slight shock at Boston, Mass.—*J. M. B.*

Feb. 3.—4 A. M. A loud report and shock at Plymouth, Mass.—*J. M. B.*

Feb. 4.—Loud report and earthquake shock at Greenland and Stratham, N. H.

Feb. 12.—A shock at Portsmouth, N. H.—*J. M. B.*

Feb. 14. A slight shock at Ukiah, Cal., "about one o'clock;" direction, east–west.—*San Francisco Chronicle.*

Feb. 26.—10.55 P. M. Slight shock at Augusta, Me.—*Augusta Journal.*

March 14.—10.30 P. M. Slight shock at Bainbridge Island, W. T.; duration, thirty seconds.—*U. S. Weath. Rev.*

March 18.—9.30 P. M. Four slight shocks at Schenectady, N. Y.—*N. Y. Times.*

March 25. About 7 P. M. a slight shock at Hebron, Utah, and Pioche, Nev.

April 3.—4.52 A. M. Slight shock at Antrim, N. H.—*U. S. Weath. Rev.*

April 5.—9.30 A. M. At San Cristobal, Cuba, a slight shock in direction S.E. to N.W.

April 7. At midnight on the morning of the 7th, a shock at St. Paul's Bay, on the St. Lawrence River, Quebec.

April 10. About 2 A. M. several severe earthquake shocks were felt in Central California. The district affected was from Sacramento, on the north, to Visalia, on the south, and from the Sierra Nevada to the coast. The time is variously stated from 2 A. M. to 2.15 A. M., and the direction at most places was east–west. At Sacramento and Merced there were two, and at Watsonville four shocks.

April 20. Shocks felt at Goshen, Indiana, with heavy rumbling.

April 21.—11.30 A. M. A heavy shock, accompanied by a rumbling noise, was felt at Port Jefferson, N. Y.—*N. Y. Tribune.*

April 21. A sharp earthquake shock in the Hawaiian Islands. —*San Francisco Chronicle.*

April 23. A passenger arriving on this date at New Orleans, from Belize, British Honduras, states that a number of severe earthquake shocks had recently occurred there and along the coast of Spanish Honduras; especially one that occurred three or four weeks previous had injured houses in Belize.—*N. Y. Times.*

April 24. The New York Tribune of this date speaks of a "recent" earthquake shock in Colorado, most severe in the vicinity of the Twin Lakes. No other report of it has come to hand.

April 27.—9.10 P. M. A shock at Los Angeles, Cal.; direction, S.W. to N.E.; duration, two seconds.—*U. S. Weath. Rev.*

May 17. During the night a shock in Hayti, causing several landslips.—*Nature.*

May 18. At Contoocook, N. H., two shocks, at 12.20 A. M. and between 3 and 4 A. M.

May 19. About 9 A. M. slight shock at Lawrence, Kan.—*Lawrence Journal.*

May 27. A shock at La Salle, Ind., in the early morning, before day.

May 31.—3.20 A. M. A heavy shock at Murray Bay and vicinity, on the St. Lawrence River, sixty miles below Quebec.

June 8. "On the night of the 8th" four shocks, one quite severe, at Greytown, Nicaragua.—*J. M. B.*

June 19. In the morning a slight shock at Ottawa, Ont.

June 19.—3.35 A. M. At Newburyport, Mass., a rumbling and shaking, lasting some seconds.

June 20.—11 A. M. Two shocks, each lasting about ten seconds, at Nickerie, Dutch Guiana. They were preceded, accompanied and followed by a rumbling sound. Barometer, 30·20 inches; thermometer, 86°.—*U. S. Weath. Rev.*

June 24 and 25. Earthquake at St. Vincents, (W. I.)—*Nature.*

June 29. Earthquake in Trinidad, (W. I.)—*Nature.*

June 30.—8 A. M. A sharp shock at Campo, Cal.; direction, S.E. to N.W., preceded and accompanied by a rumbling noise.—*U. S. Weath. Rev.*

July 2.—11 P. M. A shock at San Juan, San Benito Co., Cal. —*San Francisco Chronicle.*

July 3.—2.10 A. M. A heavy earthquake at Hanford and Visalia, Cal.; vibration, west-east in both places, accompanied by subterranean noises.—*San Francisco Chronicle.*

July 5 and 7. Earthquakes in Hayti, W. I.—*Nature.*

July 31.—9.45 P. M. A slight shock at Bangor, Me., and vicinity, felt as far distant as Dover and Augusta.

Aug. 13. An earthquake at Candoba (Cordova?), Mexico.—*San Francisco Chronicle.*

Aug. 13. A shock at Contoocook, N. H., in the early morning.—*J. M. B.*

Aug. 29. A little after 11 P. M. a slight shock at Hillsboro, Ohio, and vicinity.

Aug. 30.—7 P. M. Two slight shocks at Santa Barbara, Cal.; direction, north-south.—*U. S. Weath. Rev.*

Sept. 13. Violent shocks in Maui, Hawaiian Islands.—*U. S. Weath. Rev.*

Sept. 18.—5.20 P. M. A severe shock at San Francisco, Cal.; motion, west-east; duration, five seconds; felt also slightly at Angel Island.

Sept. 25. A slight shock at Elmira, N. Y., preceding a violent storm.

Sept. 30. About 5 A. M. a severe and destructive earthquake shock occurred in the Hawaiian Islands, followed after a few minutes by a second shock somewhat less severe. The first shock was reported from Honolulu at 4.53 A. M. Light shocks were felt through that day and three moderate ones on Oct. 1st; and the lighter tremblings continued through Oct. 3d. The earthquake appears to have been most destructive in the two Konas where many buildings and cisterns were injured.

Oct 1.—1.40 A. M. A strong shock occurred at Kamouraska, Quebec, on the south side of the St. Lawrence River. It may be remarked that twice before during the year (April 7 and May 31), this same vicinity had been shaken. St. Paul's Bay and Murray Bay are nearly opposite Kamouraska.

Oct. 2.—9 A. M. A sharp shock at Campo, Cal., accompanied by a heavy rumbling sound; direction, S.E. to N.W.; duration, eight to ten seconds.—*U. S. Weath. Rev.*

Oct. 2.—1.30 P. M. A light shock at Chilcoot, Alaska.—*U. S. Weath. Rev.*

Oct. 6. A little after midnight, on the morning of this day, a slight shock was felt at Concord and Bristol, and other neighboring places in New Hampshire; direction, east–west, and accompanied by a rumbling noise.

Oct. 6.—11 A. M. A light shock at Chilcoot, Alaska.—*U. S. Weath. Rev.*

Oct. 21.—7 P. M. At Virginia City, Nev., two shocks, each lasting about two seconds; direction, S.W. to N.E. The same shock was reported from Carson City at 6.41 P. M.; direction, south–north.

Oct. 31.—1.40 A. M. A slight shock at Contoocook, Henniker, Deering and Hillsboro, N. H.

Nov. 9.—10.10 A. M. Two sharp shocks at Virginia City and Carson, Nev., from the south.

Nov. 11.—4 P. M. and Nov. 13, 11.20 P. M. Slight shocks at San Francisco, Cal.—*U. S. Weath. Rev.*

Nov. 13. An earthquake at Iquique, Chili.—*Nature.*

Nov. 15. Severe shock at noon at San José, Cal.—*N. Y. Times.*

Dec. 4.—6.30 P. M. A slight shock at Huntingdon, Quebec; direction, west–east.

Dec. 7. A heavy shock at Eureka, Nev.—*U. S. Weath. Rev.*

Dec. 16.—4 P. M. A slight shock at Dorchester, Mass.; felt only in a small district.—*J. M. B.*

Dec. 26.—11.45 P. M. A slight shock at Kingston, Jamaica.—*U. S. Weath. Rev.*

The above record includes notices of seventy-one distinct earthquakes, of which ten are in small type. They may be classified geographically as follows:

Canada,	5	West Indies,	6
New England,	14	Guiana,	1
Atlantic States,	3	Chili,	1
Mississippi Valley,	5	Hawaiian Islands,	3
Pacific Coast,	30		
Mexico and Central America,	3	Total,	71

Of the ten doubtful items, six are in New England.

In reviewing the list it will be noticed that no earthquake during the year has affected any wide extent of country, those of April 19th, in California, and Sept. 30th, in the Hawaiian Islands, being the most extensive. Also none (unless the one just mentioned) has caused any notable damage to buildings or property. It is worthy of mention also that there are only *two* items from South America (June 20, Guiana, and Nov. 13, Chili). Has the Chili-Peruvian war interfered with our usual channels of information, or caused any earthquakes there to be unreported?

Princeton, Feb. 27, 1882.

ART. XXVII.—*Notes on the Electromagnetic Theory of Light*; by J. WILLARD GIBBS, Professor of Mathematical Physics in Yale College. No. I. *On Double Refraction and the Dispersion of Colors in perfectly transparent Media.*

1. IN calculating the velocity of a system of plane waves of homogeneous light, regarded as oscillating electrical fluxes, in transparent and sensibly homogeneous bodies, whether singly or doubly refracting, we may assume that such a body is a very fine-grained structure, so that it can be divided into parts having their dimensions very small in comparison with the wave-length, each of which may be regarded as entirely similar to every other, while in the interior of each there are wide differences in electrical as in other physical properties. Hence, the average electrical displacement in such parts of the body may be expressed as a function of the time and the coördinates of position by the ordinary equations of wave-motion, while the real displacement at any point will in general differ greatly from that represented by such equations.

It is the object of this paper to investigate the velocity of light in perfectly transparent media which have not the property of circular polarization in a manner which shall take account of this difference between the real displacements and those represented by the ordinary equations of wave-motion. We shall find that this difference will account for the dispersion of colors, without affecting the validity of the laws of Huyghens and Fresnel for double refraction with respect to light of any one color.

In this investigation, it is assumed that the electrical displacements are *solenoidal*, or, in other words, that they are such as not to produce any change in electrical density. The disturbance in the medium is treated as consisting entirely of such electrical displacements and fluxes, and not complicated by any distinctively magnetic phenomena. It might therefore be more accurate to call the theory (as here developed) *electrical* rather than *electromagnetic*. The latter term is nevertheless retained in accordance with general usage, and with that of the author of the theory.

Since the velocity which we are seeking is equal to the wave-length divided by the period of oscillation, the problem reduces to finding the ratio of these quantities, and may be simplified in some respects by supposing that we have to do with a system of stationary waves. That the relation of the wave-length and the period is the same for stationary as for progressive waves is evident from the consideration that a sys-

tem of stationary waves may be formed by two systems of progressive waves having opposite directions.

2. Let x, y, z be the rectangular coördinates of any point in the medium, which with the system of waves we may regard as indefinitely extended, and let $\xi+\xi'$, $\eta+\eta'$, $\zeta+\zeta'$ be the components of electrical displacement at that point at the time t; ξ, η, ζ being the average values of the components of electrical displacement at that time in a wave-plane passing through the point. Then ξ, η, ζ, ξ', η', ζ' are perfectly defined quantities, of which ξ, η, ζ are connected with x, y, z, and t by the ordinary equations of wave-motion, while each of the quantities ξ', η', ζ' has always zero for its average value in any wave-plane. We may call ξ, η, ζ the components of the *regular* part of the displacement, and ξ', η', ζ' the components of the *irregular* part of the displacement. In like manner, the differential coefficients of these quantities with respect to the time, $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$, $\dot{\xi}'$ $\dot{\eta}'$, $\dot{\zeta}'$, may be called respectively, the components of the regular part of the flux, and the components of the irregular part of the flux.

Let the whole space be divided into elements of volume Dv, very small in all dimensions in comparison with a wave-length, but enclosing portions of the medium which may be treated as entirely similar to one another, and therefore not infinitely small. Thus a crystal may be divided into elementary parallelopipeds, all the vertices of which are similarly situated with respect to the internal structure of the crystal. Amorphous solids and liquids may not be capable of division into equally small portions of which physical similarity can be predicated with the same rigor. Yet we may suppose them capable of a division substantially satisfying the requirements.

From these definitions it follows that at any given instant the average value of each of the quantities ξ', η', ζ' in an element Dv is zero. For the average value in one such element must be sensibly the same as in any other situated on the same wave-plane. If this average were not zero, the average for the wave-plane would not be zero. Moreover, at any given instant, the values of ξ, η, ζ may be regarded as constant throughout any element Dv, and as representing the average values of the components of displacement in that element. The same will be true of the quantities $\dot{\xi}'$, $\dot{\eta}'$, $\dot{\zeta}'$ and $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$.

3. Since we have excluded the case of media which have the property of circular polarization, we shall not impair the generality of our results if we suppose that we have to do with linearly polarized light, *i. e.*, that the regular part of the displacement is everywhere parallel to the same fixed line, all cases not already excluded being reducible to this. Then, with the origin of coördinates and the zero of time suitably chosen,

the regular part of the displacement may be represented by the equations

$$\left.\begin{aligned} \xi &= \alpha \cos 2\pi\frac{u}{l} \cos 2\pi\frac{t}{p}, \\ \eta &= \beta \cos 2\pi\frac{u}{l} \cos 2\pi\frac{t}{p}, \\ \zeta &= \gamma \cos 2\pi\frac{u}{l} \cos 2\pi\frac{t}{p}, \end{aligned}\right\} \qquad (1)$$

where l denotes the wave-length, p the period of vibration, α, β, γ the maximum amplitudes of the displacements ξ, η, ζ, and u the distance of the point considered from the wave-plane which passes through the origin. Since u is a linear function of x, y, and z, we may regard these equations as giving the values of ξ, η, ζ, for a given system of waves, in terms of x, y, z, and t.

4. The components of the irregular displacement, ξ', η', ζ', at any given point, will evidently be simple harmonic functions of the time. having the same period as the regular part of the displacement. That they will also have the same phase is not quite so evident, and would not be the case in a medium in which there were any absorption or dispersion of light. It will however appear from the following considerations that in perfectly transparent media the irregular oscillations are synchronous with the regular. For, if they are not synchronous, we may resolve the irregular oscillations into two parts, of which one shall be synchronous with the regular oscillations, and the other shall have a difference of phase of one-fourth of a complete oscillation. Now, if the medium is one in which there is no absorption or dispersion of light, we may assume that the same electrical configurations may also be passed through in the inverse order, which would be represented analytically by writing $-t$ for t in the equations which give ξ, η, ζ, ξ', η', ζ', as functions of x, y, z, and t. But this change would not affect the regular oscillations, nor the synchronous part of the irregular oscillations, which depends on the cosine of the time, while the non-synchronous part of the irregular oscillations, which depends on the sine of the time, would simply have its direction reversed. Hence, by taking first one-half the sum, and secondly one-half the difference, of the original motion and that obtained by substitution of $-t$ for t, we may separate the non-synchronous part of the irregular oscillations from the rest of the motion. Therefore, the supposed non-synchronous part of the irregular displacement, if capable of existence, is at least wholly independent of the wave-motion and need not be considered by us.

We may go farther in the determination of the quantities ξ', η', ζ'. For in view of the very fine-grained structure of the medium, it will easily appear that the manner in which the general or average flux in any element Dv (represented by ξ, η, ζ) distributes itself among the molecules and intermolecular spaces must be entirely determined by the amount and direction of that flux and its period of oscillation. Hence, and on account of the superposable character of the motions which we are considering, we may conclude that the values of ξ', η', ζ' at any given point in the medium are capable of expression as linear functions of ξ, η, ζ in a manner which shall be independent of the time and of the orientation of the wave-planes and the distance of a nodal plane from the point considered, so long as the period of oscillation remains the same. But a change in the period may presumably affect the relation between ξ', η', ζ' and ξ, η, ζ to a certain extent. And the relation between ξ', η', ζ' and ξ, η, ζ will vary rapidly as we pass from one point to another within the element Dv.

5. In the motion which we are considering there occur alternately instants of no velocity and instants of no displacement. The statical energy of the medium at an instant of no velocity must be equal to its kinetic energy at an instant of no displacement. Let us examine each of these quantities, and consider the equation which expresses their equality.

6. Since in every part of an element Dv the irregular as well as the regular part of the displacement is entirely determined (for light of a given period) by the values of ξ, η, ζ, the statical energy of the element must be a quadratic function of ξ, η, ζ,—say

$$(A\xi^2 + B\eta^2 + C\zeta^2 + E\eta\zeta + F\zeta\xi + G\xi\eta)\, Dv,$$

where A, B, etc. depend only on the nature of the medium and the period of oscillation. At an instant of no velocity, when

$$\sin 2\pi\frac{t}{p} = 0, \quad \text{and} \quad \cos^2 2\pi\frac{t}{p} = 1,$$

the above expression will reduce by equations (1) to

$$(A\alpha^2 + B\beta^2 + C\gamma^2 + E\beta\gamma + F\gamma\alpha + G\alpha\beta)\cos^2 2\pi\frac{u}{l}\, Dv.$$

Since the average value of $\cos^2 2\pi\frac{u}{l}$ in an indefinitely extended space is $\frac{1}{2}$, we have for the statical energy in a unit of volume

$$S = \tfrac{1}{2}(A\alpha^2 + B\beta^2 + C\gamma^2 + E\beta\gamma + F\gamma\alpha + G\alpha\beta). \qquad (2)$$

7. The kinetic energy of the whole medium is represented by the double volume-integral*

$$\tfrac{1}{2}\Sigma\iint\frac{(\dot{\xi}+\dot{\xi}')_1\,(\dot{\xi}+\dot{\xi}')_2}{r}\,dv_1\,dv_2$$

where dv_1, dv_2 are two infinitesimal elements of volume, $(\dot{\xi}+\dot{\xi}')_1$, $(\xi+\xi')_2$ the corresponding components of flux, r the distance between the elements, and Σ denotes a summation with respect to the coördinate axes. Separating the integrations, we may write for the same quantity

$$\tfrac{1}{2}\Sigma\int(\dot{\xi}+\dot{\xi}')_1\left[\int\frac{(\dot{\xi}+\dot{\xi}')_2}{r}\,dv_2\right]dv_1.$$

It is evident that the integral within the brackets is derived from $\dot{\xi}+\dot{\xi}'$ by the same process by which the potential of any mass is derived from its density. If we use the symbol *Pot* to express this relation, we may write for the kinetic energy

$$\tfrac{1}{2}\Sigma\int(\dot{\xi}+\dot{\xi}')\ \mathrm{Pot}\ (\dot{\xi}+\dot{\xi}')\,dv.$$

The operation denoted by this symbol is evidently distributive, so that $\mathrm{Pot}\,(\dot{\xi}+\dot{\xi}')=\mathrm{Pot}\,\dot{\xi}+\mathrm{Pot}\,\dot{\xi}'$. The expression for the kinetic energy may therefore be expanded into

$$\tfrac{1}{2}\Sigma\int\dot{\xi}\ \mathrm{Pot}\ \dot{\xi}\,dv+\tfrac{1}{2}\Sigma\int\dot{\xi}\ \mathrm{Pot}\ \dot{\xi}'\,dv$$
$$+\tfrac{1}{2}\Sigma\int\dot{\xi}'\ \mathrm{Pot}\ \dot{\xi}\,dv+\tfrac{1}{2}\Sigma\int\dot{\xi}'\ \mathrm{Pot}\ \dot{\xi}'\,dv.$$

But $\dot{\xi}'$, and therefore Pot $\dot{\xi}'$, has in every wave-plane the average value zero. Also $\dot{\xi}$, and therefore Pot $\dot{\xi}$, has in every wave-plane a constant value. Therefore the second and third integrals in the above expression will vanish, leaving for the kinetic energy

$$\tfrac{1}{2}\Sigma\int\dot{\xi}\ \mathrm{Pot}\ \dot{\xi}\,dv+\tfrac{1}{2}\Sigma\int\dot{\xi}'\ \mathrm{Pot}\ \dot{\xi}'\,dv, \qquad (3)$$

which is to be calculated for a time of no displacement, when

$$\dot{\xi}=\pm\frac{2\pi\alpha}{p}\cos 2\pi\frac{u}{l},\quad \dot{\eta}=\pm\frac{2\pi\beta}{p}\cos 2\pi\frac{u}{l},\quad \dot{\zeta}=\pm\frac{2\pi\gamma}{p}\cos 2\pi\frac{u}{l}. \qquad (4)$$

The form of the expression (3) indicates that the kinetic energy consists of two parts, one of which is determined by the regular part of the flux, and the other by the irregular part of the flux.

* The fluxes are supposed to be measured by the electromagnetic system of units. It is to be observed that the difference of opinion which has prevailed with respect to the estimation of the energy of electrical currents does not extend to such as are *solenoidal*, which may be regarded as composed of closed circuits.

8. The value of Pot $\dot{\xi}$ may be easily found by integration, but perhaps more readily by Poisson's well-known theorem, that if q is any function of position in space (as the density of a certain mass),

$$\frac{d^2 \text{Pot}\, q}{dx^2} + \frac{d^2 \text{Pot}\, q}{dy^2} + \frac{d^2 \text{Pot}\, q}{dz^2} = -4\pi q, \tag{5}$$

where the direction of the coördinate axes is immaterial, provided that they are rectangular. In applying this to Pot $\dot{\xi}$, we may place two of the axes in a wave-plane. This will give

$$\frac{d^2 \text{Pot}\, \dot{\xi}}{du^2} = -4\pi \dot{\xi}. \tag{6}$$

In a nodal plane, Pot $\dot{\xi}=0$, since $\dot{\xi}$ has equal positive and negative values in elements of volume symmetrically distributed with respect to any point in such a plane. In a wave-crest (or plane in which $\dot{\xi}$ has a maximum value), Pot $\dot{\xi}$ will also have a maximum value, which we may call K. For intermediate points we may determine its value from the consideration that the total disturbance may be resolved into two systems of waves, one having a wave-crest, and the other a nodal plane passing through the point for which the potential is sought. The maximum amplitudes of these component systems will be to the maximum amplitude of the original system as $\cos 2\pi \frac{u}{l}$ and $\sin 2\pi \frac{u}{l}$ to unity. But the second of the component systems will contribute nothing to the value of the potential. We thus obtain

$$\text{Pot}\, \dot{\xi} = \text{K} \cos 2\pi \frac{u}{l},$$

$$\frac{d^2 \text{Pot}\, \dot{\xi}}{du^2} = -\frac{4\pi^2}{l^2} \text{K} \cos 2\pi \frac{u}{l} = -\frac{4\pi^2}{l^2} \text{Pot}\, \dot{\xi}.$$

Comparing this with equation (6), we have

$$-\frac{4\pi^2}{l^2} \text{Pot}\, \dot{\xi} = -4\pi \dot{\xi},$$

$$\text{Pot}\, \dot{\xi} = \frac{l^2}{\pi} \dot{\xi}. \tag{7}$$

Hence, and by equations (4),

$$\tfrac{1}{2} \Sigma f \dot{\xi}\, \text{Pot}\, \dot{\xi}\, dv = \frac{l^2}{2\pi} \Sigma f \dot{\xi}^2\, dv = \frac{2\pi l^2}{p^2} (\alpha^2 + \beta^2 + \gamma^2) f \cos^2 2\pi \frac{u}{l}\, dv.$$

The kinetic energy of the regular part of the flux is therefore, for each unit of volume,

$$T=\frac{\pi l^2}{p^2}(\alpha^2+\beta^2+\gamma^2), \tag{8}$$

9. With respect to the kinetic energy of the irregular part of the flux, it is to be observed that, since $\dot{\xi}'$, $\dot{\eta}'$, $\dot{\zeta}'$ have their average values zero in spaces which are very small in comparison with a wave-length, the integrations implied in the notations Pot $\dot{\xi}'$, Pot $\dot{\eta}'$, Pot $\dot{\zeta}'$ may be confined to a sphere of a radius which is small in comparison with a wave-length. Since within such a sphere $\dot{\xi}'$, $\dot{\eta}'$, $\dot{\zeta}'$ are sensibly determined by the values of $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$ at the center of the sphere, which is the point for which the value of the potentials are sought, Pot $\dot{\xi}'$, Pot $\dot{\eta}'$, Pot $\dot{\zeta}'$ must be functions—evidently linear functions—of $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$; and ξ' Pot $\dot{\xi}'$, η' Pot $\dot{\eta}'$, ζ' Pot $\dot{\zeta}'$ must be quadratic functions of the same quantities. But these functions will vary with the position of the point considered with reference to the adjacent molecules.

Now the expression for the kinetic energy of the irregular part of the flux,

$$\tfrac{1}{2}\Sigma\int\dot{\xi}'\,\mathrm{Pot}\,\dot{\xi}'\,dv,$$

indicates that we may regard the infinitesimal element dv as having the energy (due to this part of the flux)

$$\tfrac{1}{2}\Sigma\xi'\,\mathrm{Pot}\,\xi'\,dv.$$

Let us consider the energy due to the irregular flux which will belong to the above defined element Dv, which is not infinitely small, but which has the advantage of being one of physically similar elements which make up the whole medium. The energy of this element is found by adding the energies of all the infinitesimal elements of which it is composed. Since there are quadratic functions of the quantities $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$, which are sensibly constant throughout the element Dv, the sum will be quadratic function of ξ, η, ζ, say

$$(A'\dot{\xi}^2+B'\dot{\eta}^2+C'\dot{\zeta}^2+E'\dot{\eta}\dot{\zeta}+F'\dot{\zeta}\dot{\xi}+G'\dot{\xi}\dot{\eta})\,Dv,$$

which will therefore represent the energy of the element Dv due to the irregular flux. The coefficients A′, B′, etc., are determined by the nature of the medium and the period of oscillation. They will be constant throughout the medium, since one element Dv does not differ from another.

This expression reduces by equations (4) to

$$\frac{4\pi^2}{p^2}(\mathrm{A}'\alpha^2+\mathrm{B}'\beta^2+\mathrm{C}'\gamma^2+\mathrm{E}'\beta\gamma+\mathrm{F}'\gamma\alpha+\mathrm{G}'\alpha\beta)\cos^2 2\pi\frac{u}{l}\,\mathrm{D}v.$$

The kinetic energy of the irregular flux in a unit of volume is therefore

$$\mathrm{T}'=\frac{2\pi^2}{p^2}(\mathrm{A}'\alpha^2+\mathrm{B}'\beta^2+\mathrm{C}'\gamma^2+\mathrm{E}'\beta\gamma+\mathrm{F}'\gamma\alpha+\mathrm{G}'\alpha\beta.) \qquad (9)$$

10. Equating the statical and kinetic energies, we have

$$\tfrac{1}{2}(\mathrm{A}\alpha^2+\mathrm{B}\beta^2+\mathrm{C}\gamma^2+\mathrm{E}\beta\gamma+\mathrm{F}\gamma\alpha+\mathrm{G}\alpha\beta)$$
$$=\frac{\pi l^2}{p^2}(\alpha^2+\beta^2+\gamma^2)$$
$$+\frac{2\pi^2}{p^2}(\mathrm{A}'\alpha^2+\mathrm{B}'\beta^2+\mathrm{C}'\gamma^2+\mathrm{E}'\beta\gamma+\mathrm{F}'\gamma\alpha+\mathrm{G}'\alpha\beta). \qquad (10)$$

The velocity (V) of the corresponding system of progressive waves is given by the equation

$$\mathrm{V}^2=\frac{l^2}{p^2}=\frac{1}{2\pi}\,\frac{\mathrm{A}\alpha^2+\mathrm{B}\beta^2+\mathrm{C}\gamma^2+\mathrm{E}\beta\gamma+\mathrm{F}\gamma\alpha+\mathrm{G}\alpha\beta}{\alpha^2+\beta^2+\gamma^2}$$
$$-\frac{2\pi}{p^2}\,\frac{\mathrm{A}'\alpha^2+\mathrm{B}'\beta^2+\mathrm{C}'\gamma^2+\mathrm{E}'\beta\gamma+\mathrm{F}'\gamma\alpha+\mathrm{G}'\alpha\beta}{\alpha^2+\beta^2+\gamma^2}. \qquad (11)$$

If we set

$$a=\frac{1}{2\pi}\mathrm{A}-\frac{2\pi}{p^2}\mathrm{A}', \qquad b=\frac{1}{2\pi}\mathrm{B}-\frac{2\pi}{p^2}\mathrm{B}', \qquad \text{etc.,} \qquad (12)$$

and

$$\rho^2=\alpha^2+\beta^2+\gamma^2,$$

the equation reduces to

$$\mathrm{V}^2=\frac{a\alpha^2+b\beta^2+c\gamma^2+e\beta\gamma+f\gamma\alpha+g\alpha\beta}{\rho^2}. \qquad (13)$$

For a given medium and light of a given period, the coefficients a, b, etc., are constant.

This relation between the velocity of the waves and the direction of oscillation is capable of a very simple geometrical expression. Let r be the radius vector of the ellipsoid

$$ax^2+by^2+cz^2+eyz+f'zx+gxy=1. \qquad (14)$$

Then

$$\frac{1}{r^2}=\frac{ax^2+by^2+cz^2+eyz+fzx+gxy}{r^2}.$$

If this radius is drawn parallel to the electrical oscillations, we shall have

$$\frac{x}{r}=\frac{\alpha}{\rho}, \qquad \frac{y}{r}=\frac{\beta}{\rho}, \qquad \frac{z}{r}=\frac{\gamma}{\rho},$$

and

$$\mathrm{V}^2=\frac{1}{r^2}. \qquad (15)$$

That is, the wave-velocity for any particular direction of oscillation is represented in the ellipsoid by the reciprocal of the radius vector which is parallel to that direction.

11. This relation between the wave-length, the period, and the direction of vibration, must hold true not only of such vibrations as actually occur, but also of such as we may imagine to occur under the influence of constraints determining the direction of vibration in the wave-plane. The directions of the natural or unconstrained vibrations in any wave-plane may be determined by the general mechanical principle that if the type of a natural vibration is infinitesimally altered by the application of a constraint, the value of the period will be stationary.* Hence, in a system of stationary waves, such as we have been considering, if the direction of an unconstrained vibration is infinitesimally varied in its wave-plane by a constraint, while the wave-length remains constant, the period will be stationary. Therefore, if the direction of the unconstrained vibration is infinitesimally varied by constraint, and the period remains rigorously constant, the wave-length will be stationary. Hence, if we make a central section of the above described ellipsoid parallel to any wave-plane, the directions of natural vibration for that wave-plane will be parallel to the radii vectores of stationary value in that section, viz., to the axes of the ellipse, when the section is elliptical, or to all radii, when the section is circular.

12. For light of a single period, our hypothesis has led to a perfectly definite result, our equations expressing the fundamental laws of double refraction as enunciated by Fresnel. But if we ask how the velocity of light varies with the period, that is, if we seek to derive from the same equations the laws of the dispersion of colors, we shall not be able to obtain an equally definite result, since the quantities A, B, etc., and A′, B′, etc., are unknown functions of the period. If, however, we make the assumption, which is hardly likely to be strictly accurate, but which may quite conceivably be not far removed from the truth, that the manner in which the general or average flux in any small part of the medium distributes itself among the molecules and intermolecular spaces is independent of the period, the quantities A, B, etc., and A′, B′, etc., will be constant, and we obtain a very simple relation between V and p, which appears to agree tolerably well with the results of experiment.

If we set

$$H=\frac{A\alpha^2+B\beta^2+C\gamma^2+E\beta\gamma+F\gamma\alpha+G\alpha\beta}{\rho^2}, \qquad (16)$$

* See Rayleigh's *Theory of Sound*, vol. i, p. 84.

and $$H'=\frac{A'\alpha^2+B'\beta^2+C'\gamma^2+E'\beta\gamma+F'\gamma\alpha+G'\alpha\beta}{\rho^2}, \quad (17)$$

our general equation (11) becomes

$$V^2=\frac{H}{2\pi}-\frac{2\pi H'}{p^2}, \quad (18)$$

where H and H′ will be constant for any given direction of oscillation, when A, B, etc., and A′, B′, etc., are constant. If we wish to introduce into the equation the absolute index of refraction (n) and the wave-length in vacuo (λ) in place of V and p, we may divide both sides of the equation by the square of the constant (k) representing the velocity of light in vacuo. Then, since

$$\frac{V}{k}=\frac{1}{n}, \quad \text{and} \quad kp=\lambda,$$

our equation reduces to

$$\frac{1}{n^2}=\frac{H}{2\pi k^2}-\frac{2\pi H'}{\lambda^2}, \quad (19)$$

It is well known that the relation between n and λ may be tolerably well but by no means perfectly represented by an equation of this form.

13. If we now give up the presumably inaccurate supposition that A, B, etc., and A′, B′, etc., are constant, equation (19) will still subsist, but H and H′ will not be constant for a given direction of oscillation, but will be functions of p, or, what amounts to the same, of λ. Although we cannot therefore use the equation to derive *a priori* the relation between n and λ, we may use it to derive the values of H and H′ from the empirically determined relation between n and λ. To do this, we must make use again of the general principle that an infinitesimal variation in the type of a vibration, due to a constraint, will not affect the period. If we first consider a certain system of stationary waves, then a system in which the wave-length is greater by an infinitesimal dl (the direction of oscillation remaining the same,) the period will be increased by an infinitesimal dp, and the manner in which the flux distributes itself among the molecules and intermolecular spaces will presumably be infinitesimally changed. But if we suppose that in the second system of waves there is applied a constraint compelling the flux to distribute itself in the same way among the molecules and intermolecular spaces as in the first system, (so that ξ', η', ζ' shall be the same functions as before of ξ, η, ζ,—a supposition perfectly compatible with the fact that the values of ξ, η, ζ are changed,) this constraint, according to the principle cited, will not affect the period of oscilla-

tion. Our equations will apply to such a constrained type of oscillation, and A, B, etc., and A′, B′, etc., and therefore H and H′, will have the same values in the last described system of waves as in the first system, although the wave-length and the period have been varied. Therefore, in differentiating equation (18), which is essentially an equation between l and p, or its equivalent (19), we may treat H and H′ as constant. This gives

$$-\frac{2}{n^3}\frac{dn}{d\lambda}=\frac{4\pi \mathrm{H}'}{\lambda^3}.$$

We thus obtain the values of H′ and H:

$$\mathrm{H}'=-\frac{\lambda^3}{2\pi n^3}\frac{dn}{d\lambda}, \qquad \mathrm{H}=\frac{2\pi k^2}{n^2}-\frac{2\pi k^3\lambda}{n^3}\frac{dn}{d\lambda}. \tag{20}$$

By determining the values of H and H′ for different directions of oscillation, we may determine the values of A, B, etc., and A′, B′, etc.

By means of these equations, the ratios of the statical energy (S), the kinetic energy due to the regular part of the flux (T), and the kinetic energy due to the irregular part of the flux (T′), are easily obtained in a form which admits of experimental determination. Equations (8) and (9) give

$$\mathrm{T}=\frac{\pi\rho^2 l^2}{p^2}, \qquad \mathrm{T}'=\frac{2\pi^2 \mathrm{H}'\rho^2}{p^2}.$$

Therefore, by (20),

$$\frac{\mathrm{T}'}{\mathrm{T}}=\frac{2\pi \mathrm{H}'}{l^2}=\frac{2\pi \mathrm{H}' n^2}{\lambda^2}=-\frac{\lambda}{n}\frac{dn}{d\lambda}=-\frac{d\log n}{d\log\lambda}. \tag{21}$$

$$\frac{\mathrm{S}}{\mathrm{T}}=\frac{\mathrm{T}+\mathrm{T}'}{\mathrm{T}}=1+\frac{\mathrm{T}'}{\mathrm{T}}=\frac{d\log\lambda-d\log n}{d\log\lambda}=\frac{d\log l}{d\log\lambda}. \tag{22}$$

$$\frac{\mathrm{T}'}{\mathrm{S}}=-\frac{d\log n}{d\log l}. \tag{23}$$

Since S, T, and T′ are essentially positive quantities, their ratios must be positive. Equation (21) therefore requires that the index of refraction shall increase as the period or wave-length in vacuo diminishes. Experiment has shown no exceptions to this rule, except such as are manifestly attributable to the absorption of light.

14. It remains to consider the relations between the optical properties of a medium and the planes or axes of symmetry which it may possess. If we consider the statical energy per unit of volume (S) and the period as constant, we may regard equation (2) as the equation of an ellipsoid, the radii vectores of which represent in direction and magnitude the amplitudes of systems of waves having the same statical energy. In like manner, if we consider the kinetic energy of the irregular part of the flux per unit of volume (T′) and the period as constant.

we may regard equation (9) as the equation of an ellipsoid, the radii vectores of which represent in direction and magnitude the amplitudes of systems of waves having the same kinetic energy due to the irregular part of the flux. These ellipsoids, which we may distinguish as the ellipsoids (A, B, etc.) and (A′, B′, etc), as well as the ellipsoid before described, which we may call the ellipsoid (*a*, *b*, etc.), must be independent in their form and their orientation of the directions of the axes of coördinates, being determined entirely by the nature of the medium and the period of oscillation. They must therefore possess the same kind of symmetry as the internal structure of the medium.

If the medium is symmetrical about a certain axis, each ellipsoid must have an axis parallel to that. If the medium is symmetrical with respect to a certain plane, each ellipsoid must have an axis at right angles to that plane. If the medium after a revolution of less than 180° about a certain axis is then equivalent to the medium in its first position, or symmetrical with it with respect to a plane at right angles to that axis, each ellipsoid must have an axis of revolution parallel to that axis. These relations must be the same for light of all colors, and also for all temperatures of the medium.

15. From these principles, we may infer the optical characteristics of the different crystallographic systems.

In crystals of the isometric system, as in amorphous bodies, the three ellipsoids reduce to spheres. Such media are optically isotropic, at least so far as any properties are concerned which come within the scope of this paper.

In crystals of the tetragonal or hexagonal systems, the three ellipsoids will have axes of rotation parallel to the principal crystallographic axis. Since the ellipsoid (*a*, *b*, etc.) has but one circular section, there will be but one optic axis, which will have a fixed direction.

In crystals of the orthorhombic system, the three ellipsoids will have their axes parallel to the rectangular crystallographic axes. If we take these directions for the axes of coördinates, E, F, G, E′, F′, G′, *e*, *f*, *g* will vanish and equation (13) will reduce to

$$V^2=\frac{a\alpha^2+b\beta^2+c\gamma^2}{\rho^2}.$$

If the coördinate axes are so placed that

$$a>b>c,$$

the optic axes will lie in the X-Z plane, making equal angles φ with the axis of Z, which may be determined by the equation

$$\tan^2\varphi=\frac{a-b}{b-c}=\frac{p^2(A-B)-4\pi^2(A'-B')}{p^2(B-C)-4\pi^2(B'-C')}.$$

To get a rough idea of the manner in which φ varies with the period, we may regard A, B, C, A′, B′, C′ as constant in this equation.

But since the lengths of the axes of the ellipsoid (a, b, etc.) vary with the period, it may easily happen that the order of the axes with respect to magnitude is not the same for all colors. In that case, the optic axes for certain colors will lie in one of the principal planes, and for other colors in another. For the color at which the change takes place, the two optic axes will coincide. The differential coefficient $\frac{d\varphi}{dp}$ becomes infinitely great as the optic axes approach coincidence.

In crystals of the monoclinic system, each of the three ellipsoids will have an axis perpendicular to the plane of symmetry. We may choose this direction for the axis of X. Then F, G, F′, G′, f, g, will vanish and equation (13) will reduce to

$$V^2 = \frac{a\alpha^2 + b\beta^2 + c\gamma^2 + e\beta\gamma}{\rho^2}.$$

The angle θ made by one of the axes of the ellipsoid (a, b, etc.) in the plane of symmetry with the axis of Y and measured toward the axis of Z is determined by the equation

$$\tan 2\theta = \frac{e}{c-b} = \frac{p^2 E - 4\pi^2 E'}{p^2 (C-B) - 4\pi^2 (C'-B')}.$$

To get a rough idea of the *dispersion* of the axes of the ellipsoid (a, b, etc.) in the plane of symmetry, we may regard B, C, E, B′, C′, E′, as constant in this equation, and suppose the axis of Y so placed as to make E vanish.

It is evident that in this system the plane of the optic axes will be fixed, or will rotate about one of the lines which bisect the angles made by the optic axes, according as the mean axis of the ellipsoid (a, b, etc.) is perpendicular to the plane of symmetry or lies in that plane. In the first case the *dispersion* of the two optic axes will be unequal. The same crystal, however, with light of different colors, or at different temperatures, may afford an example of each case.

In crystals of the triclinic system, since the ellipsoids (A, B, etc.) and (A′, B′, etc.) are determined by considerations of a different nature, and there are no relations of symmetry to cause a coincidence in the directions of their axes, there will not in general be any such coincidence. Therefore the three axes of the ellipsoid (a, b, etc.), that is, the two lines which bisect the angles of the optic axes and their common normal, will vary in position with the color of the light.

16. It appears from this foregoing discussion that by the electromagnetic theory of light we may not only account for the dispersion of colors (including the dispersion of the lines

which bisect the angles of the optic axes in doubly refracting media), but may also obtain Fresnel's laws of double refraction for every kind of homogeneous light *without neglect of the quantities which determine the dispersion of colors.*

But a closer approximation than that of this paper will be necessary to explain the phenomena of circularly polarizing media, which depend on very minute differences of wave-velocity, represented perhaps by a few units in the sixth significant figure of the index of refraction. That the degree of approximation which will give the laws of circular and elliptic polarization will not add any terms to the equations of this paper, except such as vanish for media which do not exhibit this phenomenon, will be shown in another number of this Journal.

ART. XXVIII.—*The "Timber Line;"* by HENRY GANNETT.

IN Dr. Rothrock's valuable report on botany, recently published by the "Surveys West of the 100th Meridian," the author quotes Dr. Engelmann's statement that "there is little or no increase in altitude in the timber line toward the equator, in our western hemisphere, south of the 41st parallel of north latitude."

This statement is approximately true regarding the Rocky Mountains, owing, however, not to any general principle, but to what may be termed an accident of topography. Even here a decided rise is observable from 41° to 39° of latitude. In the Sierra Nevada, the Basin and Wahsatch Ranges, the statement does not hold good, the timber line rising rapidly as the latitude decreases. Again, on the volcanic peaks of the Mexican plateau, the timber line is higher by several thousands of feet than it is anywhere in the United States.

Barring the prohibitive circumstances of absence of soil and moisture, the height of the timber line is purely a question of temperature. The latter is a function of the latitude, the elevation, and the mass, of the country in the neighborhood. A great mass of country, if raised to a considerable height above the sea, as in the case of the great Cordilleran plateau of the West, carries up with it, to a certain extent, the isothermals. A glance at Mr. Schott's admirable isothermal charts amply illustrates this general fact. Washington, D. C., has a mean annual temperature of 55° Fah., while Denver, Col., a fraction of a degree farther north, and at an elevation of 5,300 feet, has a mean temperature, not of 37°, as the height might indicate, but of 49°.

Therefore, in considering the height of the timber line, we must regard the mountain ranges in connection with the plateaus upon which they stand, their latitudes, heights and masses, or what, in a measure, sums up these three, their temperatures, as it is by these that its height is determined.

Looking at the subject from this point of view, a fair comparison may be instituted between the timber line in different latitudes and on different ranges in the same latitude.

The actual elevation above sea level of the timber line in the Cordilleras of North America ranges from 6 or 7,000 to 12,000 feet. It is lowest in the Coast and Cascade Ranges of Washington Territory, where it is at about the former figures. Following the Cascade Range southward into Oregon, the timber line rises to a height of 7,000 to 8,000 feet. It continues to increase as we trace it southward into California, being on Shasta and the neighboring mountains 8,000 feet above the sea. On the high sierras of Eastern central California, forests grow to 10,000 or 11,000 feet, while the San Bernardino and other ranges of Southern California do not reach the upper limit of forests.

Few of the ranges of Nevada reach the timber line, which is at a height of 9,000 feet in the north up to, probably, 11,000 feet in the southern part of the State.

In Arizona, probably none of the mountains reach the timber line, except the volcanic group known as the San Francisco Mountains, and the Sierra Blanca. On these the timber line is between 11,000 and 12,000 feet.

In New Mexico, it averages about 12,000 feet above sea level. There is little variation between the northern and southern parts of the territory, as the higher annual temperature of the southern part is fully compensated for by the greater altitude of the plateau in the northern part.

In Colorado, it ranges from 12,000 feet in the southern part to 11,000 in the north. It is highest in the great mass of the San Juan Mountains and in the Sangre de Cristo range, and lowest in the northern portions of the Park and Front Ranges.

In Southern Wyoming, in the Park range, which is the only one in this portion of the territory which rises above the limit of timber, this limit is at about 11,000 feet. In the Wind River and Téton Ranges, in the northwestern part of the territory, it is at an elevation of 10,000 to 11,000 feet.

In Montana and Idaho, the limit of timber is, in general, from 9,000 to 10,000 feet, being highest in the south, and lowest near the northern boundary.

In the Uinta and Wahsatch Ranges of Utah, it is about 11,000 feet, rising somewhat above this figure in the southern part of the latter range.

Thus it is seen that in the same latitude, there is a very marked difference in the height of the timber line. The less the elevation of the surrounding country, other things being equal, the lower is the limit of timber.

This suggests a farther point. The upper limit of timber must have approximately the same mean annual temperature everywhere. Of course it will differ to a slight extent in different localities, owing to difference of exposure to wind and sun, but these are mere local circumstances, not affecting the general principle. The determination of this temperature accurately is, without direct observation, of course, impossible. I have, however, computed it approximately from such data as are available, and have found tolerably close accordance among the results.

The mean annual temperature decreases about 1° Fah. for each 300 feet of abrupt ascent. In the case of Pike's Peak and Colorado Springs, where the difference of elevation is more than 8,000 feet, the change is 1° for each 295 feet. In the case of Mt. Washington and Shelburne, New Hampshire, it is 325 feet for each degree. The former case is the most favorable in every respect, and as most of our results are drawn from the western region, I have adopted, as a round number, 300 feet.

Now, if the average mean annual temperature all around the base of a mountain were known, it would be a very simple matter to determine, with some accuracy, the temperature at timber line, knowing its height and the mean height of its base. The nearest approach which can be made to this, is to assume that the station or stations at or near the base, represent the average climate, a supposition which, in many cases, is by no means correct. Using, however, in the manner indicated, such data as are at hand, I have obtained the following results:

Mountains, etc.	Height of timber line, feet.	BASE STATION.			Temperature at timber line.
		Name.	Height in feet.	Mean an. tem.	
Cunningham Pass, Colo.,	11,500	Fort Garland,	7,945	43°	31°
Mt. Lincoln, Colo.,	12,051	Fairplay,	9,965	38°	31°
Mt. Silverheels, Colo.,	11,549	"	9,965	38°	33°
Mt. Guyot, Colo.,	11,811	"	9,965	38°	32°
Mt. Powell, Colo.,	11,600	White River Agency.	6,491	45°	28°
Pike's Peak, Colo.,	11,720	Colorado Springs,	6,032	48°	29°
Gray's Peak, Colo.,	11,100	Denver,	5,244	48°	29°
Wahsatch Mts., Utah.	10,000	Salt Lake City,	4,350	52°	33°
Mt. Washington, N. H.,	4,150	Shelburne, N. H.,	700	42°	30°
Mt. Marcy, N. Y.,	4,851	Somerville, N. Y.,	412	45°	30°
" "	4,851	Plattsburgh, N. Y.,	180	44°	29°
Mt. Blackmore, Mont.,	9,550	Fort Ellis, Mont.,	4,935	44°	29°
Mt. Bridger, Mont.,	9,002	" "	4,935	44°	31°
Mt. Delano, Mont.,	8,784	" "	4,935	44°	31°

The mean of these results is 30°·4, and this is probably very near the true mean annual temperature of the timber line. The better the conditions of the determination, the nearer are the results to this mean. Mts. Blackmore and Bridger are very good cases, being on the border of the Gallatin Valley, in which Fort Ellis is situated, and but very few miles distant from the latter. Mts. Lincoln and Silverheels are also admirably situated with respect to Fairplay, but the annual temperature of the latter station is not well determined. Pike's Peak and Colorado Springs make an excellent pair of stations, being but ten miles apart, and the annual temperature at the latter place being well determined by the observations of the Signal Bureau. On the other hand, Mt. Powell and the White River Agency are widely separated by many miles of high plateaus, which may materially change the conditions of the temperature about the mountain.

Should this result, when tested by a wider range of observations, hold good, it will afford a very valuable and easily obtainable isothermal, and also enable one to estimate the height of the timber line from thermometric stations at the bases of mountain ranges.

Art. XXIX.—*Simple Method for Calibrating Thermometers*; by Silas W. Holman.

The calibration of a thermometer by most of the methods in ordinary use is a tedious and somewhat difficult operation, and hence often neglected even in important work. For the purpose of supplying a method simple both in observation and computation, and at the same time accurate, the following process is described, which, although involving little that is novel, has not to my knowledge been used before.

First, however, it is necessary to recall to the attention of observers the fact that, without calibration correction, the readings of a thermometer having a scale of equal linear parts cannot be relied upon within one or more divisions of this scale; and that thermometer makers, knowing this, almost universally space the graduation upon the tube to correspond more or less closely with the shape of the bore, as determined by previous calibration, or by comparison with a standard (!) instrument. This practice is much more general than is ordinarily supposed, and has an important bearing upon the accuracy of the work done with such instruments. For the scale thus made is merely approximate, the dividing engine or other tool being usually changed only at such intervals as to make

the average error less than some specified amount. An inspection of these conditions will show that the calibration of such a tube and scale can be only approximate except with corrections for the inequalities of the spacing, involving an amount of labor disproportionate to the result attained. The best makers, such as Fastré, Baudin and others, have produced satisfactory thermometers graduated to equal volumes; but even these are not as reliable as instruments of less cost with a scale of equal linear parts, say of millimeters, supplemented by a calibration by the observer. The best form of tube for almost all work is one backed with white enamel, with an inverted pear-shaped bulb at the upper end of the capillary (a very important feature), and with a scale of equal arbitrary linear parts (0·7 mm. to 1 mm. is a suitable length for estimation of tenths) or of approximate degrees, for convenience, etched or engraved upon it.

Without reviewing here the methods proposed by various writers, it may be said that it has been the general plan to select beforehand upon the scale two points between which to make the calibration, this space being the "calibration unit," the errors of these points being, of course, zero. This plan has led to unnecessary complexity. Such an assumption is no more requisite in calibration after a scale has been put upon the tube, than in calibrating by the dividing-engine or micrometer before making the scale. It is obvious that the selection of these points is wholly arbitrary, and, if used at all, one or both of them may, if desirable, be chosen after the observations with the calibrating thread have been made. The choice should be made with the view to facilitating the work. Hence the use of the observed freezing and boiling points, upon which some methods are based, is most undesirable.

In the method which will now be given, either one or both of these points may be left to be selected, according to the combined conditions of length of thread employed, shape of the tube, and numerical convenience, after the observations with the thread have been made.

Let it be desired to find the calibration corrections for a given tube. Determinations which will give the errors of every 3 cm. of length will ordinarily be sufficient, but this must depend on the result sought. Separate a thread of mercury of about that length. The actual length of the thread within two or three millimeters is of no consequence whatever, and hence a suitable thread can be obtained in a very short time.

Set the thread with its lower end at or near the beginning of the graduation: call the reading * of the lower end of the

* Tenths of a division are supposed to be read by estimation.

thread l_1, and that of the upper end u_1. Move the thread less than 1 mm. and read again, finding thus l_2 and u_2. Move the thread about 1 cm. and read l_3 and u_3. Move the thread less than 1 mm. and read l_4 and u_4. So continue throughout the whole length of graduation, increasing the number of settings or repeating the whole series in reverse order and several times if the highest attainable precision is desired. This alternation between 1 mm. and 1 cm. in setting tends towards the better elimination of errors in estimation. It is not, however, essential, nor even always as well as an equal number of distributed readings. This must depend upon the skill of the observer. Avoid, as far as convenient, taking readings with an end of the thread apparently just at the line of the scale, as the width of the line, even in the best scales, is a source of considerable error.* If any point, e. g., the zero point of the graduation, has for any reason been selected as the first of which the error should be assumed zero, the settings may to advantage, though not necessarily, be made to extend each way from this.

Then u_1-l_1, u_2-l_2, etc., will give a series of lengths of the calibrating thread in all parts of the tube. Before reuniting this thread to the rest of the mercury, plot points with abscissas l_1, l_2, etc., and ordinates u_1-l_1, u_2-l_2, etc., the corresponding lengths of thread, and draw a smooth curve through the points thus obtained. This line will give a general idea of the form of the capillary bore; and, should any parts of it show considerable irregularities, the corresponding portions of the tube should at once be re-explored with the thread.

If not already done, the point A, upon the scale, to be used as the starting or reference point of the computation, should now be selected. In general the extreme ends of the tube are to be avoided, as more likely to have been rendered irregular or rapidly tapering in the process of making or joining on the bulbs. If the zero of the numbering is placed one or two centimeters from the bottom of the tube it forms a desirable starting point.

Find upon the curve the ordinate u' corresponding to the abscissa A; then with abscissa $A+u'$ find the corresponding ordinate u''; with abscissa $A+u'+u''$, find the corresponding ordinate u''', continuing to the upper limit of the graduation. If A is at a sufficient distance from the lower end of the graduation, find a similar series below the point A. These points, A, $A+u'$, $A+u'+u''$, etc., upon the graduation are separated by equal volumes of the capillary. Select any one of these as the second point of which the error is to be arbitrarily

* Some of the advantages of Neumann's method are offset by this error.

assumed as zero, and call this B. Then $A+u'+u''+ \ldots + u^{nth}=B$. There are thus n spaces of equal volume between A and B, and these correspond each to $\frac{1}{n}$th of the interval B–A. Hence the true reading (which, however, it is not necessary to compute numerically) at the point—

A	is	A
$A+u'$	"	$A+\frac{1}{n}(B-A)$
$A+u'+u''$	"	$A+\frac{2}{n}(B-A)$
. . . .		. . . .
B	"	B

And the error obtained by subtracting the true readings, as given in the right-hand column, from the corresponding actual readings, given in the left-hand column, at

A	is	0
$A+u'$	"	$A+u'\{A+\frac{1}{n}(B-A)\}=u'-\frac{1}{n}(B-A)$
$A+u'+u''$	"	$u'u''-+\frac{2}{n}(B-A)$
. . . .		. . . .
B	"	0

In selecting B it might have been assumed equal to $A+u'$, thus making $n=1$. This would somewhat simplify the calculation, and would be of equal accuracy, but is objectionable from the fact that, in general, this volume would differ considerably from the average volume obtained when n has a greater value (always an integer), and the resulting series of errors would assume larger numerical values.

The errors or corrections are, for purposes of interpolation, most conveniently represented graphically by a smooth curve through points with abscissas proportional to the direct readings,

$$A,\ A+u',\ A+u'+u'',\ \text{etc.},$$

and ordinates to the corresponding corrections.

Should it be necessary to increase the accuracy by a second calibration with a thread of different length, it is only necessary to take one of approximately an integral part of (B–A), and when the final curve of error is drawn, make the error at B equal to zero, distributing the difference at that point proportionally to the scale readings, among the errors at the in-

termediate points: in other words, to shift the axis of the second curve of error so that it shall make the error at B zero.

This method requires for each calibration the use of but a single thread. The computation is simple, and involves a minimum of approximation. Errors of observation are largely eliminated by the number of settings made in all parts of the tube, and by the inspection of the curve of lengths, both of which operations tend in an unusual degree to detect mistakes or any minor irregularities of the capillary. It avoids the common requirements of setting the thread exactly at certain definite points in the tube, or any approximate correction for slight errors in such setting,—two sources of considerable error and inconvenience, especially when the thread must be set near or under a line of the graduation. And, lastly, the total time of calibration for a result of given accuracy is reduced to one-half or one-third of that required by Neumann's method, the quickest and most satisfactory with which I am acquainted except that given by Pickering. The latter, described with some slight inaccuracies, at the reference noted below, is a neat application of the graphical method; and the curve of lengths of thread adopted in the method which I have described is identical with the corresponding one given by Professor Pickering, while the whole process is fully one-third shorter and somewhat more accurate. From a series of calibrations executed upon the same thermometer (one with a millimeter scale, by Baudin, of Paris), using a variety of methods, I have obtained slightly more concordant results with the proposed method than with Neumann's or Pickering's, all those possessing, however, nearly the same degree of precision, and decidedly better results with these than with any of the other existing simple methods.

Considerable aid in eliminating errors of parallax in such work is sometimes found by looking down upon the horizontal thermometer through a vertical tube having a small hole at each end. One of the cheap French microscopes with its lenses removed, and inverted in its stand, answers this purpose well.

With such a device two calibrations of the above described thermometer with threads of 3 cm. and 5 cm. respectively, each with only one series of observations, and requiring not more than one hour and a half each for completion, gave results whose average difference from each other at nine points was 0·04 mm., and the arithmetical sum of the extreme differences was 0·12 mm., a result of sufficient accuracy for any class of work of which such an instrument is capable.

For brief descriptions of methods of separating threads of mercury for calibration, reference may be made to the paper

by Russell, and the text-book by Pickering, noted below. These processes are in general use, and are safe and convenient.

Mass. Institute of Technology, Boston, Feb. 1, 1882.

References upon Calibration of Closed Thermometer Tubes.

Bessel—Pogg. Ann., vi, 287 (1826).
Rudberg—Pogg. Ann., ix, 353, 566.
" " xxxvii, 376 (1836).
" " xl, 39, 562 (1837).
Kohlrausch—Physical Measurements, p. 59 [Engl. Transl.].
Pickering—Physical Manipulation, ii, 75 (1876).
Thiesen—[Neumann's Meth.], Carl's Rep., xv, 285 (1879).
Russell—[" " Transl. from Thiesen.] Amer. Jour. Sci., xxi, 373 (1881).
Marek—Carl's Repertorium, xv, 300 (1879). [Solution by least squares.]
von Oettingen—Inaug. Diss., Dorpat, 1865. [This I have been unable to obtain.—S. W. H.]

Art. XXX.—*Physics of the Earth's Crust;* by the Rev. Osmond Fisher, M.A., F.G.S.*

Mr. Osmond Fisher has long been known to geologists as a writer upon the higher and more difficult problems connected with the evolution of the earth's physical features. His qualifications for this kind of discussion are rare to an extreme degree, for he possesses extended knowledge of geological science considered as a category of observed facts, and unites to it both wisdom and knowledge in physical science and great skill in mathematical analysis. Such men are indeed rare, and the need for them is very urgent. For upwards of ten years papers by him have appeared in the Transactions of the Cambridge Philosophical Society and in the Journal of the Geological Society, the more important of which deal with the mechanical problems arising in inquiries as to the origin of the earth's features. These papers are almost unique, for they are attempts to apply quantitative as well as qualitative tests to the various theories which have been advanced to account for such features. The present work takes those papers, originally disjointed, and with the addition of much new matter, shapes them into a well proportioned whole, with a strong bond of connective logic running through it.

* Physics of the Earth's Crust. By the Rev. Osmond Fisher, M.A., F.G.S. pp. 299, 8vo. London: Macmillan & Co. 1881.

The first chapter is upon Underground Temperature, and recites those observed facts which lead to the universally received opinion that the earth's interior is hot. These can be stated very briefly. They are, 1st, the observed increase of temperature as we penetrate the strata, and 2d, volcanic phenomena. These considerations are so familiar that no extended discussion is given to them. The main work of the chapter is devoted to an examination of the case presented by the artesian boring at Sperenberg in Prussia, which was believed by Prof. Mohr to lead to the inference that at the depth of only a mile the temperature ceased to augment with increasing depth. Mr. Fisher shows that these observations, though apparently anomalous at first sight, are probably not so in reality. He holds it to be a just inference that everywhere throughout the earth's external shell the temperature increases at a nearly uniform rate for each locality for 25 or 30 miles, below which horizon the increment becomes notably less rapid, and that below 160 miles at most there is no noteworthy increase. This result flows from the application of Fourier's theorem of the conduction of heat and from the amplification of that theorem by Sir William Thomson.

The second chapter has reference to the physical condition of the earth's interior. Here the conclusions are necessarily very limited. As regards the distribution of density, it is satisfactorily established that the mean density being about 5·5 and the external density about 2·65, the density of the interior approaches that of the metals, iron, silver, etc., and probably increases toward the center, but the law of increase is wholly unknown. For the purposes of subsequent discussion, it is much more essential to frame some reasonable provisional hypothesis regarding the solidity or fluidity of the earth. The physicists claim that the phenomena of tides demand extreme rigidity in the earth mass, while geological considerations demand a notable degree of interior plasticity if not liquidity. As a compromise, Mr. Fisher asks whether the demands of both parties may not be met by postulating a large solid nucleus and solid crust with an intervening layer of plastic magma. Such a construction could be accounted for (plausibly at least) by regarding the solidity of the nucleus as due to pressure and the solidity of the crust as due to cooling: while the intervening shell is nearly as hot as the nucleus and maintains the liquid condition because it is subject to a lighter pressure.

The third chapter is a quantitative investigation of the densities and pressures existing at various depths which follow from assuming 1st, the law adopted by Sartorius von Waltershausen, and 2d, the law of Laplace.

In the fourth chapter he proceeds to some of the geological

aspects of the subject. The outward appearance of the crust of the earth indicates that it has been subjected to great violence. The distortions of the crust and also the special phenomena of volcanism, demand a source of energy for their explanation. Within the earth we know of heat and gravitation as possible sources of such energy. Have these really been the agents, and if so, in what specific manner have they acted? The compression to which strata seem to have been subjected, is very generally explained by the hypothesis that the interior of the globe has contracted through secular cooling, while the crust collapsing upon the shrinking nucleus becomes wrinkled and distorted. Mr. Fisher proceeds to compute the intensity of the compressive force which would be generated in a tangent to the crust upon this supposition, and finds it to be about 830,000 tons upon the square foot. So far as intensity is concerned, there can be no doubt of the sufficiency of this pressure.

Having shown the sufficiency of this factor he then proceeds to inquire (Chapter V) whether the work has really been accomplished in this way. He begins by seeking for some measure of the inequalities of the surface: taking first the greater inequalities; the oceanic basins and continents. If the existing inequalities of the surface were leveled down and spread out they would, he estimates, form a layer over the whole earth from 9,500 to 13,000 feet thick—an under- rather than an over-estimate.

In the next chapter he proceeds to inquire how great are the inequalities which might have been produced by secular cooling. Using Thomson's adaptation of Fourier's law of cooling, he computes that even upon the most extravagant assumption the inequalities would not amount to more than a layer 900 feet thick, and upon a moderate assumption 200 feet would be nearer the mark.

So great is this discrepancy that the contractional hypothesis becomes wholly incompatible with the theory of a solid globe, and we seem compelled to conclude either (1) that the inequalities are not due to compression, or (2) some other cause than the contraction of a solid globe through mere cooling must be sought. In this chapter also, Mr. Fisher brings out some considerations which are of crushing and destructive weight against the contractional hypothesis as ordinarily conceived. Yet he regards the facts of nature to be substantial proof of the reality of great lateral compression, and he requires "a liquid or at least plastic substratum for the crust to rest on which will allow it to undergo a certain amount of lateral shift." If this be granted many things will become explicable. From a liquid or plastic substratum it would follow that the position of

rest in the crust would be approximately the position of hydrostatic equilibrium. Mr. Fisher assumes this plastic substratum henceforward through the remainder of his work.

The subsequent chapters are devoted chiefly to a consideration of the consequences which would flow from the following postulates, both of which Mr. Fisher regards as being forced upon our conviction by the nature of the facts to be explained.

1st. That lateral compression has acted upon a grand scale in developing the earth's physical features; 2d, that the earth has an inflexible crust resting upon a liquid or plastic substratum. It would be impossible in so brief a notice to do justice to the many ingenious, suggestive and valuable ideas he throws out in this discussion and only the most striking ones can be alluded to.

Mr. Fisher inclines to the following explanation of the origin of mountains. He recognizes difficulties in it but it avoids more difficulties than any other he can think of. Granting a plastic substratum of somewhat greater density than the crust, it is possible that the compression of the strata (from whatsoever cause arising) may be localized in a narrow belt or zone. At this disturbed tract, as he calls it, where the yielding takes place, the crust becomes thickened greatly. But its position of rest must observe the law of hydrostatic equilibrium or simple flotation. If by means of compression the amount of *lighter* crust-matter is increased in any locality it displaces *denser* matter in the plastic substratum. The height to which the surface of the disturbed tract will rise above the mean level will be proportional to the difference of densities of crust and substratum respectively and also to the amount of local thickening of the crust by the compression. The ratio of the density of the crust to the density of substratum he takes at about 0·905, which is not far from that of ice to water. Hence when a disturbed tract of the crust is thickened by compression much the greater part of the thickening consists in additions to the under surface of the crust and only a small part in additions to the upper surface. The bulge downward is some nine times greater than the bulge upward. Mr. Fisher's great difficulty here is in finding an adequate source of so great an amount of compression. He examines the possibilities of contraction by secular cooling and of contraction by the extravasation of volcanic effluvia and rejects both as being totally inadequate. As a last resort he suggests with much diffidence the following as a possible source, viz: the opening of fissures in the under portion of the crust, which being filled with elastic vapors are at once subjected to great horizontal compression. Although this suggestion appears at first untenable it would be simple justice to Mr. Fisher to read his exposition of it before passing

judgment upon it. The discussion cannot be briefly summarized.

In his view, volcanic energy is the motive power in producing compression; thus reversing the hypothesis of Mallett who derived volcanic energy from compression. Mr. Fisher also derives from his construction a mechanism for volcanic action, but since it is impossible to abstract his view and do it justice, the reader must be referred to the work itself.

If we may venture to sum up in a very few sentences the general tenor of this book we should say that its earlier and middle chapters show that interior contraction cannot be the source or origin of the earth's physical features. Nevertheless Mr. Fisher feels that the facts presented by the disturbed tracts of the earth's crust compel us to assume that they have been subject to great compression, and we have no alternative but to accept this as a fact plain, simple and taught clearly by Nature herself. Failing to find beneath the crust any source of compression agreeing in amount and kind with that demanded by the facts he seeks one within the crust itself. The opening of fissures in the under surface of the crust which are filled at once by elastic vapors would, he thinks, supply the requisite machinery not only of compression but also of volcanic action.

In this work Mr. Fisher has rendered extremely valuable service to the science of physical geology, and chiefly to that branch which deals with its largest and noblest problems. My own thoughts have for some years run so much in the same paths, that it would be most pleasant to speak at considerable length upon many points he has discussed, but I can advert to only a few of them. First and foremost he has rendered most effectual service in utterly destroying the hypothesis, which attributes the deformations of the strata and earth's crust, to interior contraction by secular cooling. No person, it seems to me, can sufficiently master the cardinal points of his analysis, without being convinced that this hypothesis is nothing but a delusion and a snare, and that the quicker it is thrown aside and abandoned, the better it will be for geological science.

But while he has overthrown the hypothesis of contraction by secular cooling, there are possibly a few geologists, who may feel constrained to take the ground so ably maintained by Professor LeConte, that if there has been no appreciable contraction by secular cooling, there has been some other cause of interior contraction; for contraction is, they think, absolutely necessary to explain the physical features of the earth. Mr. Fisher has touched—all too briefly it seems to me—upon an argument quite as fatal to this modified form of the theory, as the one he has so fully elaborated, and indeed, of a more direct and comprehensive character. For

the features to be explained are not such as would have been produced by contraction. The strains set up in the crust by a shrinking nucleus would be such, that for any given amount of corrugation with the axes in one direction, there must be an equal amount with the axes at right angles to that direction. The localization of mountain chains and plications in long narrow belts, with the axes of the folds all approximately parallel, with no corresponding plications at right angles to them, is an impossible result of a collapsing spherical shell. It certainly seems as if those who advocate contraction had inferred that the tangential strains set up by such a cause, would act only in two opposite directions; whereas, since they must be uniformly distributed over the entire spherical surface, they must act in every direction within a tangent plane at any point.

Mr. Fisher's postulate of a solid crust, resting upon a plastic substratum, is one which seems indispensable to any rational theory of terrestrial physics. It will hardly be questioned by any geologist. Indeed, is not the proof of it abundant and complete? Surely no one can question the fact that the vast bodies of strata deposited in all areas of maximum sedimentation have sunk bodily as rapidly as they accumulated. The Paleozoic strata of Western Europe and Eastern America, the Carboniferous and Mesozoic system of the west, were accumulated in comparatively shallow waters with the surface of deposition almost constantly near sea-level. But if they progressively sank in this way they must have displaced yielding matter beneath. How could it have been otherwise? In the face of a conclusion sustained by evidence so irrefragable, it is certainly to be hoped that no geologist will have his faith at all shaken by any purely theoretical conclusions which may have been reached by physicists in their discussions of the effects of tidal strains upon the earth. Mr. Fisher, however, proposes a very fair compromise to the physicists. He might be understood as saying to them, "give me a rigid crust resting upon a plastic substratum, and you may do what you like with the remainder." If this concession does not meet the requirements of the physicist so much the worse for the tidal argument. In truth the position of the geologist here is incomparably the stronger of the two. The plasticity of at least a thin shell next below the solid external rocks has a validity of the highest order. Reasoning or induction scarcely enter into it—it is substantially an observed fact. But the tidal argument is open to the charge of a well-known form of logical fallacy which used to be described as "proving too much." It asserts that the earth must be inconceivably rigid, otherwise we should have no tides. But we have the tides and nobody seriously believes in the transcendental rigidity.

Perhaps the best feature of Mr. Fisher's book is the skillful use he makes of a direct consequence or corollary of a plastic substratum. The elevations and depressions of the different portions of the earth's surface, he argues, are, on the theory of a plastic substratum, determined by hydrostatic laws alone. Rigidity can have but slight influence upon them. For rigidity is a quantity which relatively decreases as the magnitudes of the masses involved increase. In the continental and oceanic areas, in great plateaus and mountain systems, rigidity is a vanishing quantity, and even in individual ridges of grand proportions it probably has no great value, as compared with the forces which produce elevations and depressions. The profiles of the earth therefore become, in their broader features, simply those which are due to flotation. The higher portions float higher because they are less dense; the depressed portions sink deeper because they are more dense. The manner in which Mr. Fisher treats this very obvious consequence of a plastic substratum is most admirable. It is one of the fundamental doctrines of his book.*

Having proceeded thus far it is somewhat surprising that Mr. Fisher did not advance one step farther. Elevations and depressions (considered as actual movements) mean one of two things. (1.) Either the quantity of matter underlying the vertically moving surface, has been increased or diminished, or else (2.) the volume of underlying matter has increased or diminished. The change is either a local change of mass or a change of density. The contractional hypothesis is an attempt to obtain an increase of mass in elevated regions, and a constant mass in the depressed regions. It has signally failed and so must any theory of this purport fail: for later investigations are more and more firmly establishing the fact, that elevated regions are not regions of greater mass nor are depressed regions, regions of less mass; but the contrary. And even if the conclusion sought were for a moment supposed to be true, the continents and great plateaus, as Mr. George Darwin has recently shown, could not be sustained without a transcendentally rigid globe: much less could they with a very rigid globe ever have been pushed up. It only remains to seek the required solution in causes which will produce *local* changes of density. This dilemma is by no means sought. We are apparently driven to it by the most inexorable of logical necessities. Here the question subdivides. Shall we assume that these

* I have long been convinced that this doctrine must form an important part of any true theory of the earth's evolution. In an unpublished paper I have used the terms isostatic and isostacy to express that condition of the terrestrial surface which would follow from the flotation of the crust upon a liquid or highly plastic substratum:—different portions of the crust being of unequal density. Isobaric would have been a preferable term, but it is preoccupied in hypsometry.

changes of density are all so many varying degrees of increased density, or shall we boldly assume that local expansion is a cause of upheaval and the reverse a cause of depression? Mr. Fisher has shown the difficulty which attends the former view. There is no difficulty in supposing that the crust and subcrust to a depth of 100 to 150 miles (not the true interior be it observed) may have contracted its volume. It may have done so unequally in different portions. But the differences of elevation in various parts of the earth are too great to admit of reasonable explanation in this way. Still more serious and even fatal is the fact that some regions have alternately risen, sunk and risen again. Calling this "columnar" contraction to distinguish it from nuclear contraction, it must be said that columnar contraction alone cannot explain the facts. I see no resource but to call to our aid columnar expansion. It will at once be objected that physical science furnishes us no warrant in the known processes of nature for such an assumption. Very true. Let us all go to work therefore, and try to find a warrant for it.

C. E. DUTTON.

Art. XXXI.—*Notes on Physiological Optics*, No. III; by W. LeConte Stevens.

1. Theory of Associated Muscular Action.

In previous articles[1] it has been shown that the current theory of binocular perspective applied to the stereoscope is not only incapable of accounting for many observed facts but unsatisfactory even when the visual lines are convergent; that the apparent position of points in the stereoscopic field of view cannot be determined by any mathematical formula or accurately represented by diagram; and that this impossibility is due to physiological conditions attendant upon the abnormal use of the eyes.

That convergence of visual lines should be deemed a necessary condition in binocular vision, or, if not necessary, at least invariably present, and that it should be assumed, either expressly or implicitly, in most, if not all, of our text-books, is doubtless due to the fact that theoretically the stereoscope is intended to reproduce as nearly as possible the conditions attendant upon normal binocular vision of the objects pictured. Sir David Brewster gave especial emphasis to the theory that every point in the field of view is determined by triangulation with visual lines, elaborating this idea first in an article,[2] published in 1844, "On the Knowledge of Distance given by

Binocular Vision," and subsequently in his book on the Stereoscope,[3] published in 1856. Professor W. B. Rogers contributed to this Journal in 1855 and 1856 a series of most interesting articles on Binocular Vision,[4] in which he determined mathematically what should be the form of the resultant curve when images of dissimilar lines are binocularly combined, each point of each curve being determined by intersection of visual lines. I have performed most of Professor Rogers' experiments successfully with optic divergence. The same remark applies to those of Professor LeConte, wherever the combination is effected by diminution of the convergence that would be natural in ordinary vision.

In 1862, Professor C. F. Himes, at that time of Troy University, published an article[5] in which he criticised Brewster's theory and called attention to the modification necessitated by the possibility of stereoscopic vision with divergence of visual lines. This article, which was sent me by the author immediately after the publication of my paper in November last in this Journal, establishes his priority in this country in discovering the possibility of stereoscopic vision by this method. In 1861 two Germans, Rollet and Becker, published a method of combining similar images by optic divergence, the possibility of doing this having been already mentioned by Burckhardt.[6] Professor Himes' observations were made without any knowledge of what had just been accomplished in Germany. My own discovery was likewise independent; finding however that others had preceded me, and that prisms had been often employed to test the external rectus muscles. I claimed nothing on this ground, but devoted my attention to the analysis of vision by optic divergence; for on this little had been written. My rejection of Brewster's theory and the expression of my conviction that in associated muscular action is to be found the explanation of what has generally been referred to intersection of visual lines, was publicly made in my papers, read June 6th and Aug. 19th, 1881, the latter having since been published in this Journal. It is a source of satisfaction now to find, in the London Lancet, of Oct. 22d, and Dec. 31st, 1881, two able papers written by Brigade Surgeon Tyler Oughton, of the English army, who with no knowledge of what had been expressed by me, reaches conclusions closely akin to my own, substituting for the current theory that of "muscular consent," and rejecting the theory of corresponding retinal points.

It is but right to add that this theory was virtually stated by Professor Huxley[7] in 1868, and in such a way as quite plainly to indicate its applicability to the phenomena of optic divergence. That he should have been satisfied with a brief statement that has passed almost unnoticed, instead of elabo-

rating it in refutation of Brewster's theory, was probably due to the fact that the fallacy and popularity of the latter, in its application to the stereoscope, had not been brought especially to his attention.

2. Relation between Different Elements of Binocular Perspective.

The fact that in all stereoscopic vision there is necessarily an interruption of the usual relation between the axial and focal adjustments of the eyes was first noticed by Professor W. B. Rogers, who makes however no reference to the production of any disturbance of perspective, as noticed by myself. In the articles already published it has been shown that even when the stereograph is so constructed as to exclude to the utmost the ordinary elements of perspective, there are left still three to consider. These are—

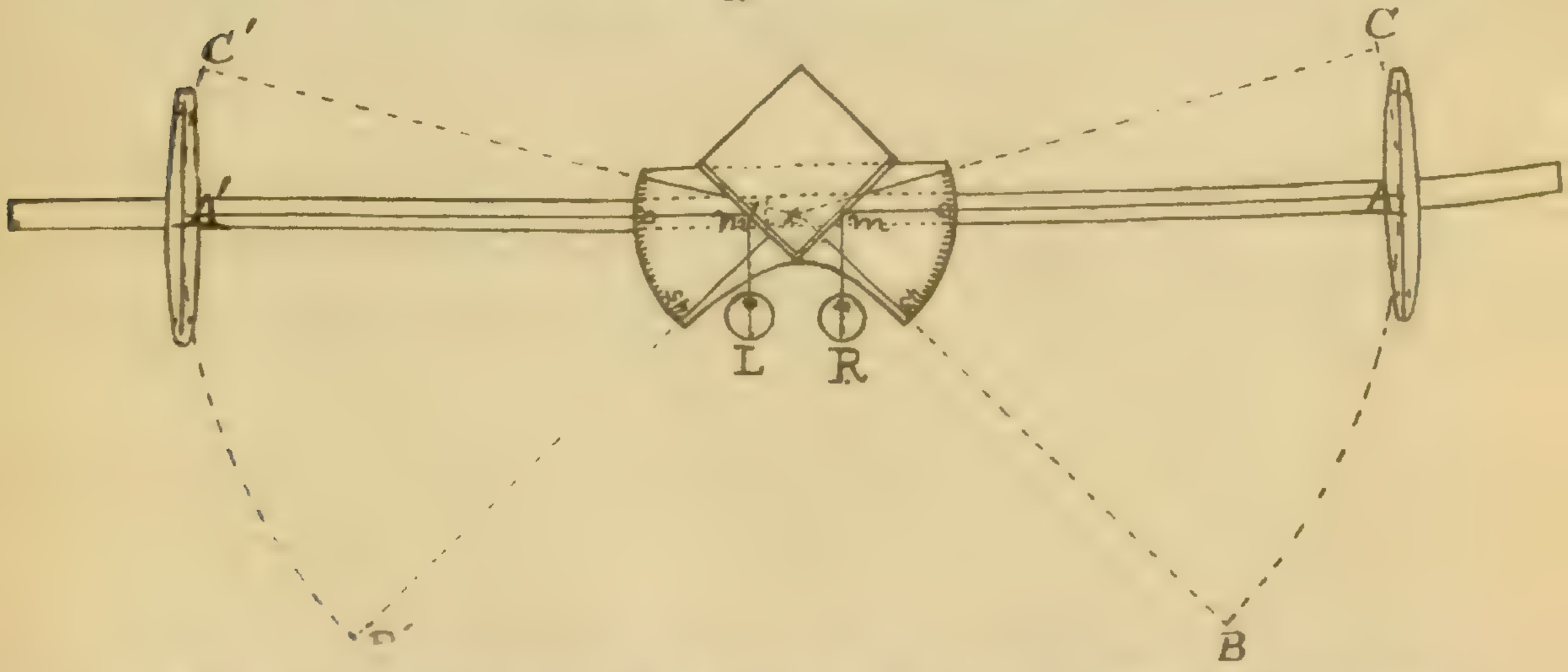
I. The optic angle, positive or negative, enclosed by the visual lines and interpreted through the sensation of contraction or relaxation in the rectus muscles of the eyeballs.

II. The focal adjustment, interpreted through the sensation of contraction or relaxation in the ciliary muscle encircling the crystalline lens.

III. The visual angle, subtended by the diameter of the object regarded, and interpreted by recognition of the retinal area impressed but instantly and unconsciously referred to the external object.

With a view to finding, if possible, what relation these three elements bear to each other in abnormal vision like that in the stereoscope, I constructed a modification of the instrument originally devised by Wheatstone. Upon a cubical block,

1.



(fig. 1) two plane mirrors, *m* and *m'*, were cemented, and a pair of arms were attached to carry the conjugate pictures. A and

A′. These arms move upon a pivot, each through an arc of 60°, under a divided circle. When so adjusted that the angle of incidence on each side is 45°, the direction of the reflected rays is such as to necessitate parallelism of visual lines for those which come from the centers of A and A′ respectively. If the arms are pulled forward for example to B and B′, the angle of incidence becomes such that the eyes must be made to roll inward to retain binocular combination of images; if pushed back toward C and C′, divergence of visual lines is necessitated. The value of the optic angle, positive for convergence, negative for divergence, is obtained, with but trifling error, from the circle. On each side let the picture be kept at a fixed distance, while the eyes are as near as possible to the mirrors, for example, so that $Am + mR = 50^{cm}$. For this distance, in normal vision, the value of the optic angle would be 7° 20′. If each arm therefore be pulled forward 3° 40′, the binocular image appears in full relief about 50^{cm} in front. Shifting the head slightly to one side, the rays from one picture are reflected by a single mirror into both eyes, and the image now appears flat at the distance of 50^{cm}. The apparent distance of this flat image is obviously independent of the relation between the arms of the instrument, and serves as a standard of comparison, the optic angle, focal adjustment and visual angle all conducing to the same judgment of distance.

Modifying slightly the formula hitherto employed, we have, for the distance, D, of the optic vertex from each eye, determined by intersection of visual lines,

$$D = \tfrac{1}{2} i \operatorname{cosec} \tfrac{1}{2}\alpha,$$

where i is the interocular distance, and α the optic angle. If this equation be expressed as a curve, fig. 2, taking values of α for abscissas and values of D for ordinates, the axis of ordinates is obviously an asymptote.

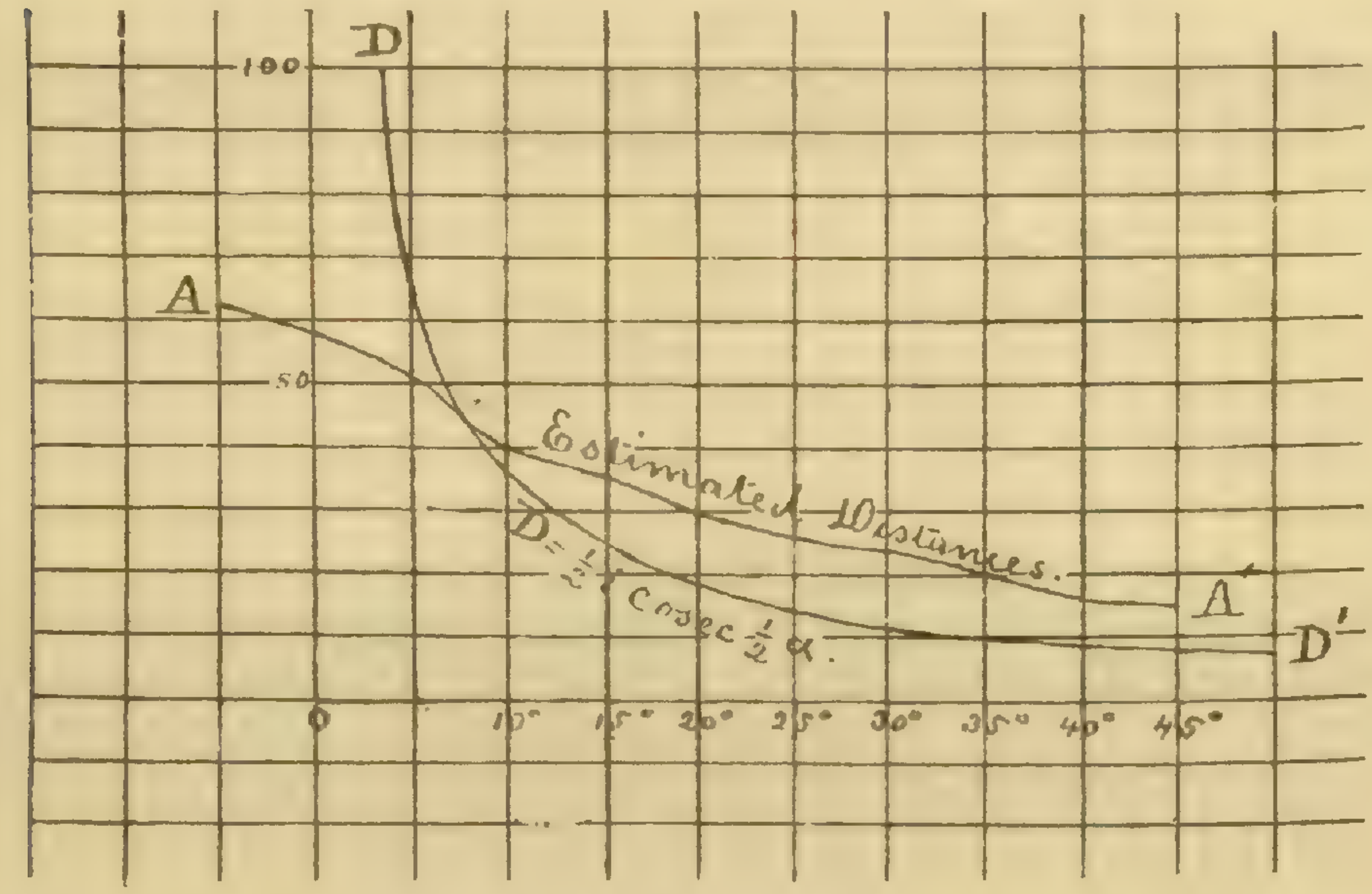
Let the arms now be pulled forward until $\alpha = 37° 20'$. The corresponding value of D is 10^{cm}, while the visual angle is unchanged and the focal adjustment, if perfectly distinct vision be secured, must still be for a distance of 50^{cm}. These two elements therefore tend to counteract the suggestion due to strong convergence, and the image appears perhaps 15^{cm} or 20^{cm} distant. Its apparent diameter varies directly as the estimated distance, and is diminished to ·3 or ·4 of the original diameter. The influence of axial convergence, though partially counteracted, preponderates over that of the other elements in determining the judgment.

Let the arms now be pushed back until $\alpha = -7°$. The theoretic value of D is negative and hence physically impossible, but practically the contraction of the external rectus muscles

produces the impression of continued recession in a positive direction. The visual angle has not been changed, and the focal adjustment not enough so to produce any very perceptible decrease in distinctness of vision. The image appears perhaps 60^{cm} or 70^{cm} distant, but this estimate is quite uncertain. The apparent diameter is of course increased. The effect of constancy in the visual angle in this case seems to be the preponderating element in determining the judgment.

The results of experiment with the apparatus just described are given in the curve A A′, of Fig. 2. The stereograph em-

2.



ployed was one of the full moon, so arranged as to produce reversion of relief. Distances were estimated to the edge of the concavity, which was surrounded with a uniform black surface. It is seen that the curve of theoretic distances, DD′, is cut by that of apparent distances, AA′, not far from the point corresponding to $\alpha = 7° 20'$. The stereoscope was manipulated by an assistant who varied the optic angle in irregular order, recording each value, of which I remained ignorant, and at the same time recording my corresponding estimate of distance. The curve has been constructed from the record of six independent series of estimates. In consequence of the difficulty of securing perfect dissociation between axial and focal adjustments for large positive values of the optic angle, 45° has been taken as a limit, though 80° of convergence is possible. For negative values the dissociation is not difficult, but beyond −5°, the image is apt to be unsteady. As might be expected, the curve is not regular, the probable error being $\pm 8^{mm}$. It is found almost to coincide with the theoretic curve for a short distance on each side of the intersec-

tion, but the judgment is much vitiated as we depart from the conditions of normal vision. Even for $\alpha = 7° 20'$ my estimate of distance was too small, and as a whole the curve shows strikingly how fallacious must be any conclusions drawn from Brewster's theory that there is a necessary connection between apparent distance and optic convergence, or, as he expressed it, that we "see distance," instead of judging it as contended by Berkeley.

The curve also shows that, under the conditions imposed, the variation in apparent distance is not very great between the limits of $-2°$ and $+5°$, within which the optic angle is included in most cases of binocular vision with lenticular stereoscopes. This explains my remark in a former article that the judgment of absolute distance is "in practice nearly, but not quite, independent of the optic angle,"[7] but is influenced rather by physical perspective. In these cases, it will be observed, the field of view is quite limited, and the optic angle not very large.

Sir David Brewster[3] noticed the strong effects obtained with convergence of visual lines by combining the images of perfectly similar patterns, recurring regularly and in great number, on large surfaces. When an extended field of view is occupied by such images, the effect of contraction in the rectus muscles seems to be more marked in comparison with that of the other elements of perspective, in estimating absolute distance there being no contrast of background and foreground to interfere. This enhancement is noticeable also when the visual lines are made to diverge, but still the positive visual angle is more important than the negative optic angle in determining the resultant effect. This is well shown by the following experiment: A large vertical surface is found upon which there are regularly recurring figures separated from each other by an interval 3^{mm} in excess of my interocular distance. Standing 50^{cm} off, in front, the images of contiguous pairs are combined by axial divergence, the optic angle being very nearly $-0° 21'$. The illusion is that of a papered wall about 3^{m} distant. Approaching them until the divergence is doubled, the wall appears about 2^{m} distant. The increase of divergence tends to produce the effect of apparent recession, but this is much more than counteracted by increasing the visual angle as the true distance is diminished, causing the externally projected image to appear to approach from the further side, instead of receding. The size of the retinal image varies in accordance with a well known law, but optic divergence slightly modifies the interpretation that would otherwise be suggested by the sensation. The apparent distance and diameter are thus made to vary together at will. Comparing the for-

mer, however, 3^m, with that expressed in the curve A A′, 58^{cm}, for the same negative optic angle, and the same real distance, 50^{cm}, it is seen that the change of conditions has produced a great change in the unconscious interpretation of the retinal image. In both cases the facts contradict Brewster's theory of triangulation. Brewster[3] himself noticed that when the combined image is small in comparison with the whole field of view, it did not appear at its calculated distance, even with convergence of axes, and to get rid of the disturbance due to comparison he resorted to large surfaces with geometrical patterns, but evidently without suspecting that optic divergence in viewing them was possible.

While the curve A A′, fig. 2, represents the result of experiment upon myself alone, similar results have been obtained from the examination of several other persons. In each case the range of uncertainty has been large, and the curve of theory has been found to be crossed by that of experiment near the point corresponding to the optic angle of normal binocular vision. Estimated distances were always greater or less than distances calculated by use of the formula, according as the optic angle was greater or less than that of normal vision at the true distance of the object regarded. For small and negative angles, not only is the departure of the curve of experiment from that of theory very rapid, but the uncertainty in the estimate of distance is increased. For larger angles the two curves approach more nearly to coincidence if the observer is well practiced and at the same time presbyopic, so that ciliary adjustment interferes less with the suggestion due to axial adjustment.

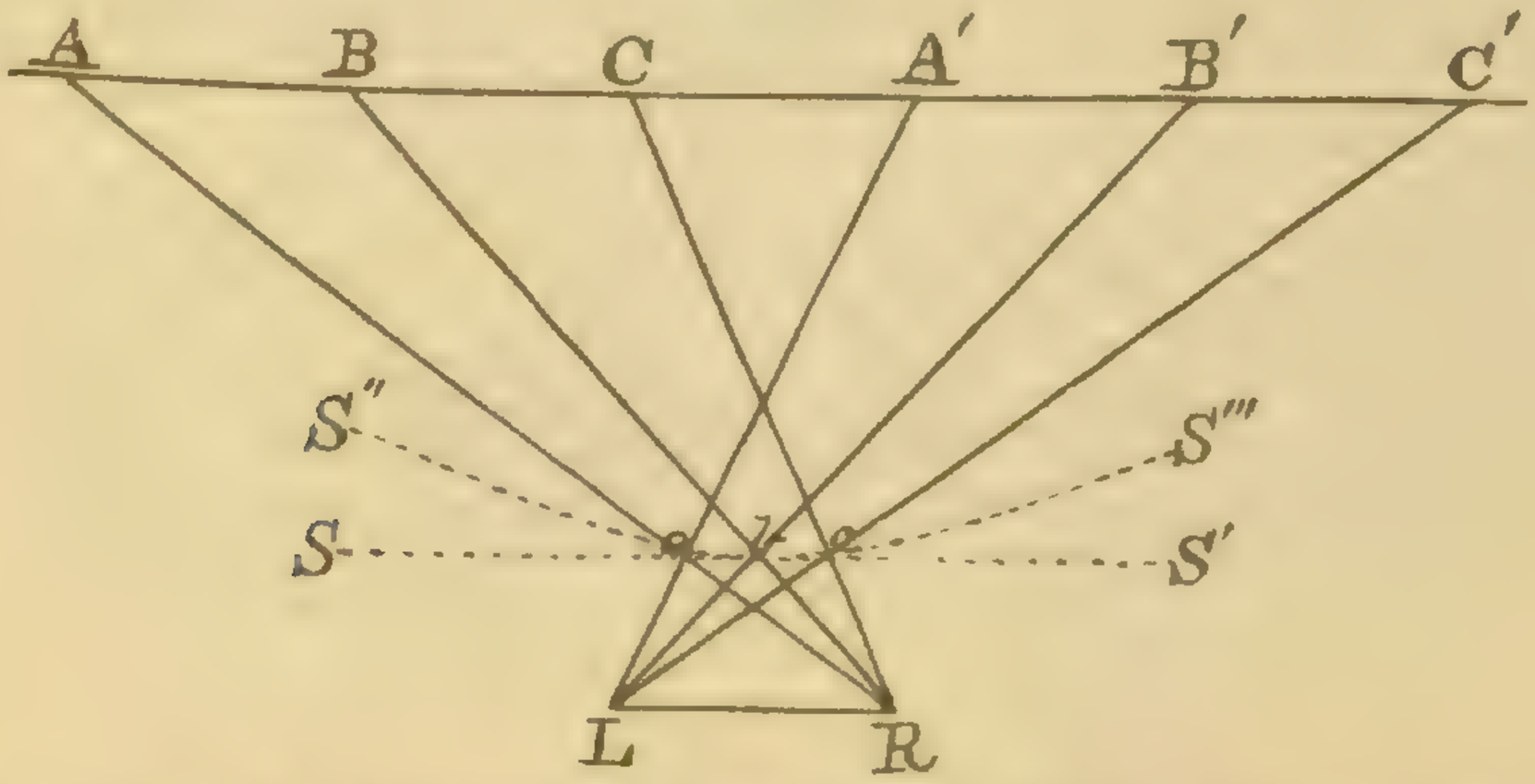
There are several considerations which interfere still further, in comparing results obtained from different observers. One person may be less accustomed than another to depend upon the sensation of muscular strain in interpreting visual perceptions. The definiteness of the interpretation becomes less as the departure from normal conditions increases. The same degree of convergence or divergence may imply greater muscular strain for one pair of eyes than for another, according to the elasticity and vigor of the muscles, or the age of the individual. Even when the real distance of the object is varied with the optic angle according to the formula so that there is no departure from the conditions of normal vision, the estimates of each observer will be found to be affected with a nearly constant error, as has been shown by the experiments of Helmholtz and Wundt.[8] This error was more than 33 per cent of the true distance in many of Wundt's experiments. In abnormal vision, furthermore, the dissociation between axial and focal adjustments is usually not instantaneous, and for strong

convergence it is very limited. The curve A A′ might perhaps have approached more nearly that of theory had I waited longer for ciliary adaptation, but this in turn involved great fatigue in the rectus muscles, especially when many experiments in succession were made, and the error was as great from this cause as from imperfect dissociation. Brewster observes, in reference to the binocular image obtained by forced convergence,[2] that "it generally advances slowly to its new position," and he speaks of "the influence of time over the evanescence as well as the creation of this class of phenomena." The nature of focal accommodation by action of the ciliary muscle was not then known—(1844).

3. A New Mode of Stereoscopy.

The study of physiological perspective has enabled me to attain the explanation of a phenomenon first observed by Brewster, but not explained by him, and directly contrary to his theory of visual triangulation. In viewing with strong cross-vision a large plane surface on which are regularly recurring figures, such as wall paper, a phantom image of the wall is easily obtained, which appears suspended in mid-air. Of this image Brewster observes in passing, that "the surface seems slightly curved,"[9] but discusses this feature no further. His explanation[10] of the production of the phantom wall is easily understood. Let A, B, C, etc. (fig. 3), be equidistant points on the

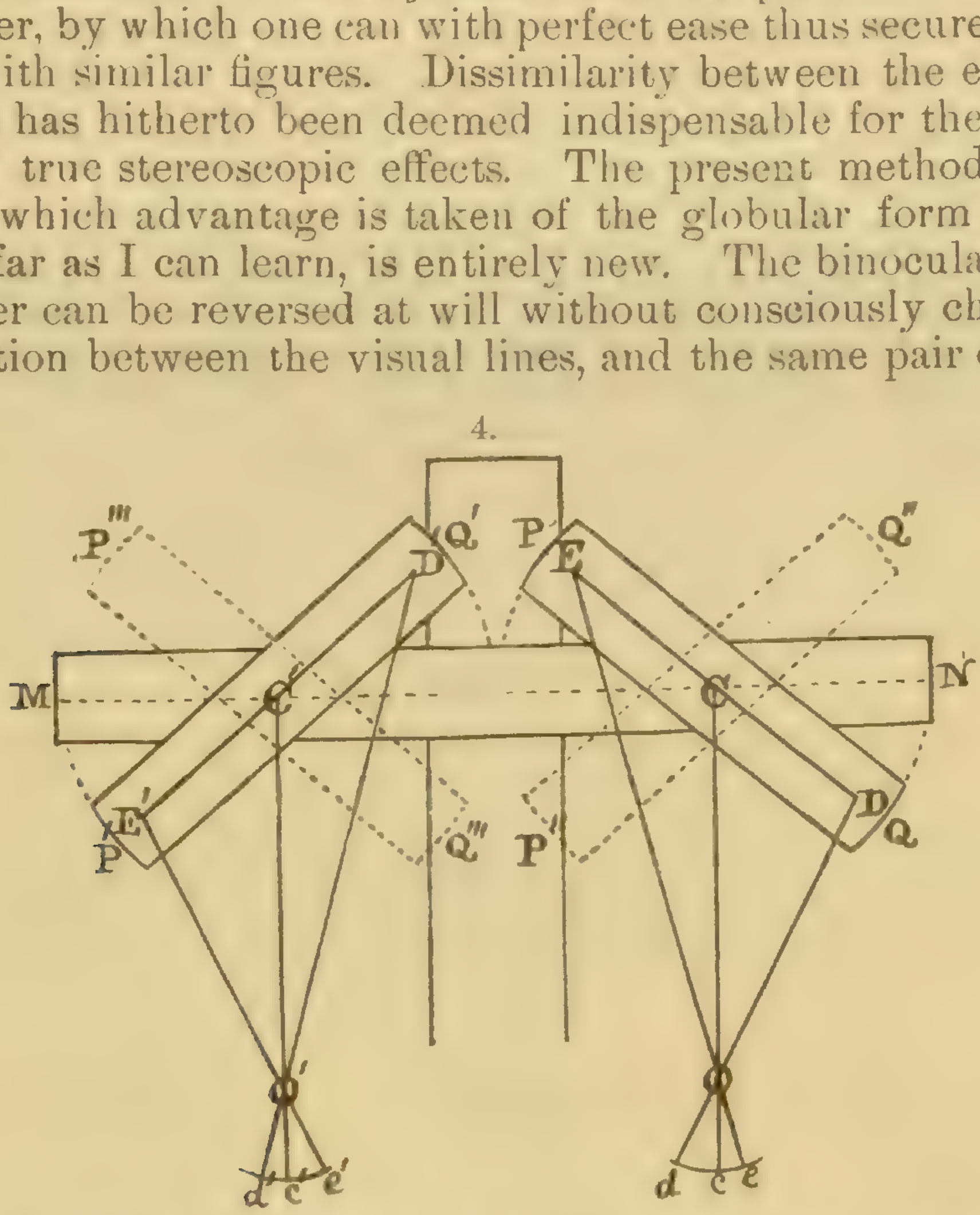
3.



wall, in front of which stands the observer whose eyes are at R and L. If the right eye be directed to A and the left to A′, the intersection of visual lines is at *a*. In like manner, *b* and *c* are determined, and it is an obvious geometric necessity that the locus of the phantom surface must be a plane S S′ parallel to the given plane AC. assuming the line L R to be parallel to it also. It cannot be a curve S″ S‴, if the theory be true. To make the curvature apparent, the optic angle must be large: and on account of the exceeding muscular strain it in-

volves, the experiment has probably been rarely tried, and soon passed into oblivion. The curvature of the phantom surface, in a median plane passing vertically between the eyes, was rediscovered a short time ago by Professor LeConte, and soon afterward I discovered the curvature in all directions.

The effect is in no way due to intersection of visual lines, but to the opposite obliquity of vision with each eye separately, combined with the fact that the retinal surface is not plane but almost spherical at the points impressed, the center of curvature being very near the nodal point of the crystalline lens. The experiment is therefore far easier and more striking if optic parallelism or slight divergence be substituted for strong convergence, and if, instead of a wall, a pair of cards be employed, on which are perfectly similar figures, such as a pair of similar series of concentric circles. If there be difficulty in directing the eyes, an ordinary stereoscope can be used as an aid. I have devised a simple attachment for the adjustable stereoscope described in my last paper, by which one can with perfect ease thus secure stereoscopy with similar figures. Dissimilarity between the external pictures has hitherto been deemed indispensable for the attainment of true stereoscopic effects. The present method therefore, in which advantage is taken of the globular form of the eye, so far as I can learn, is entirely new. The binocular relief moreover can be reversed at will without consciously changing the relation between the visual lines, and the same pair of simi-



lar pictures can be examined with comfort while in form the binocular image changes from an elliptic convex shield to a flat circular plate and thence into a deep elliptic cup; the process being reversed at pleasure.

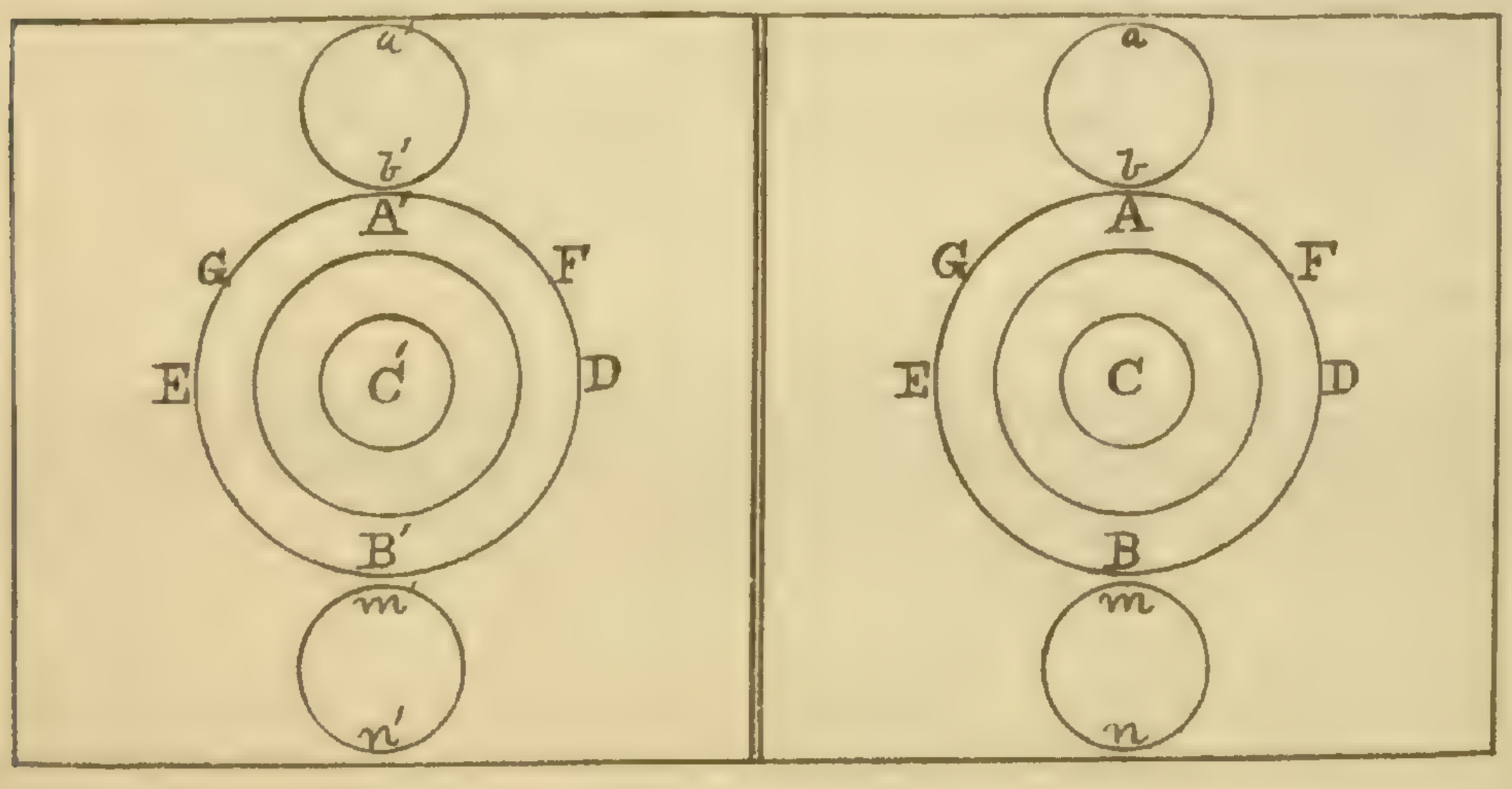
The attachment consists of an ordinary cross-bar, M N, fig. 4, which may be placed as near as convenient in front of the eyes whose optic centers are at O and O′, the visual lines being parallel and passing through points C and C′. These are the centers of the conjugate series of concentric circles, on cards whose planes are perpendicular to the principal plane of vision, and which rest on extra short bars, P Q and P′Q′. The latter are pivoted on the cross-bar so as to revolve about vertical axes passing through C and C′ respectively. Let E D and E′D′ be the horizontal diameters of the largest circles, the cards having been revolved so as to make with each other a dihedral angle opening toward the observer. Their relation to the visual lines is obviously the same as if their planes were coincident and the visual lines crossed, making the optic angle equal to the sum of N C D and M C′E′, as in Brewster's experiment. The retinal projections of E C D and E′C′D′ are $e\,c\,d$ and $e'c'd'$. Since the triangles E O D and E′O′D′ are oblique, their medians divide the angles at O and O′ unequally: hence $d\,c > c\,e$ and $d'c' < c'e'$. The retinal images in the two eyes are hence dissimilar; and this dissimilarity may be made so great by increasing the angles N C D and M C′E′ that the binocular image becomes confused if the eyes are not made to play rapidly over the picture. If the attention be momentarily withdrawn from C and C′ to D and D′, the visual lines become divergent to an extent measured by the difference of the angles D O C and D′O′C′. The associated contraction of the external rectus muscles which this necessitates at once produces the sensation that habitually accompanies recession of the object binocularly viewed. The same is true if the attention be restored to C and C′, and then given to E and E′. The binocular image of the horizontal diameter must hence be perceived as a curve, convex toward the observer.

Each circle moreover must be projected upon the retina approximately as an ellipse whose minor axis is horizontal, its ratio to the major axis being readily calculable if the angle of inclination be known. But the retinal ellipses are no longer concentric (figures 5 and 6), the extent of retinal displacement depending on the extent of the minor axis in each. If the successive vertices be connected, we have two curved lines, A C B and A′C′B′. If these be binocularly combined and externally projected, since C C′ is less than A A′ and B B′, optic divergence becomes necessary in transferring the attention from C and C′ to A and A′ or B and B′. The binocular image of the vertical diameters must hence be perceived as a curve, convex toward the observer.

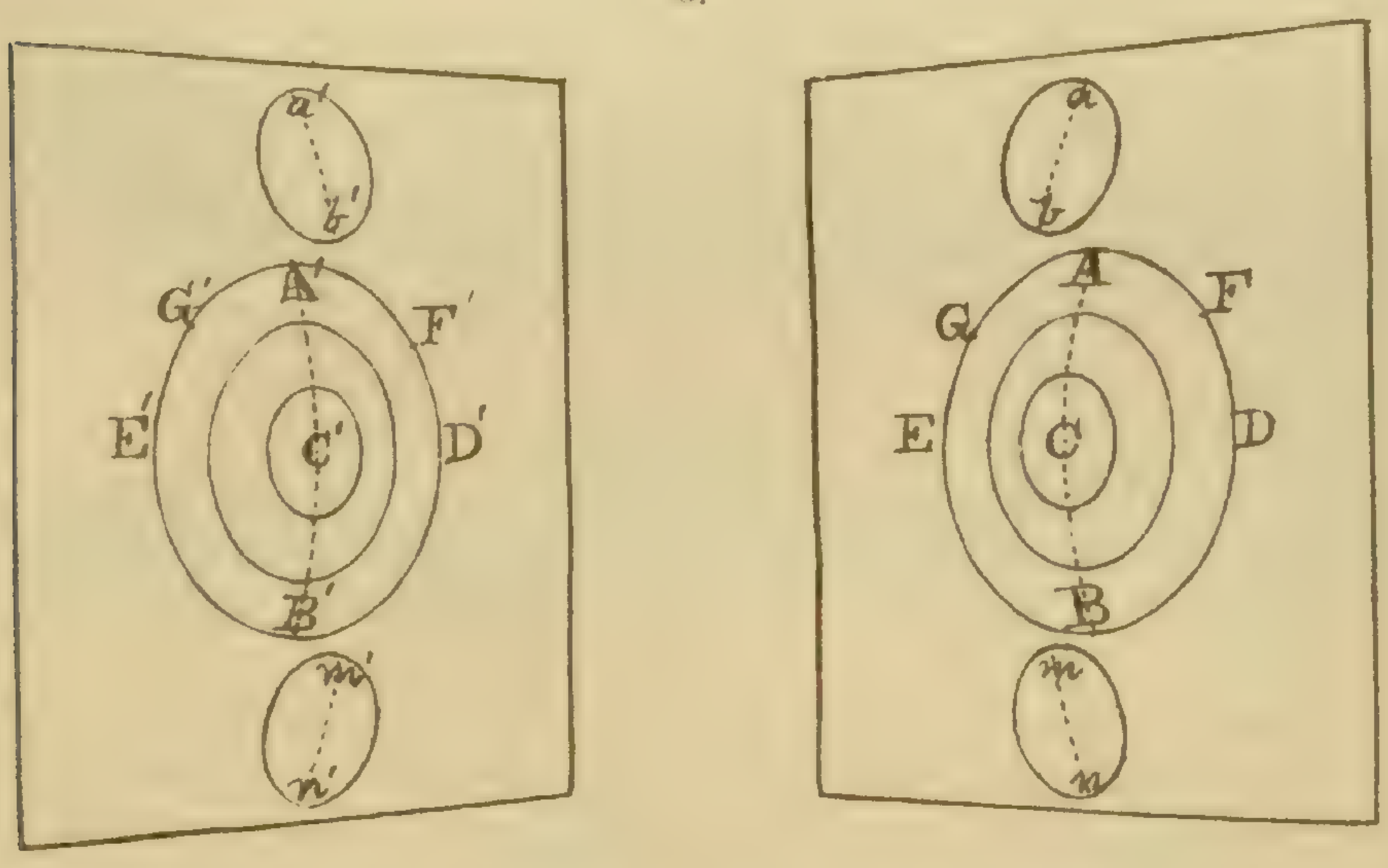
Let F and G (fig. 5) be points symmetrically situated with regard to the vertical diameter and hence equidistant from D

and E respectively. When the card is revolved, as in fig. 4, the distance O E exceeds O D, and hence the visual angle subtended by E G is less than that subtended by D F. Every ellipse therefore is distorted. To each eye separately the effect

5.



6.



is the same as if every major axis were bent, and every point of each curve were correspondingly displaced: F and G′ are elevated, F′ and G depressed, and hence F and F′ differ in retinal latitude as well as longitude. The binocular combination, however, is perfect, although double images due to difference in retinal latitude are neither homonymous nor heteronymous. That conjugate points differing slightly in altitude can be binocularly viewed and their images combined, even when there is no horizontal stereoscopic displacement, was first shown by Professor W. B. Rogers." This is one of several considerations which show that the theory of corresponding points in binocu-

lar vision cannot be accepted in any mathematical sense. In the present case the distortions of the retinal ellipses, being equal and opposite in the two eyes, are perfectly corrected in the binocular combination of each pair; the resultant curves are hence perfect ellipses.

If a pair of small circles whose vertical diameters are $a\,b$ and $a'b'$ be drawn above the large circles, the visual lines directed to their centers are similarly oblique to their vertical diameters but oppositely oblique to their horizontal diameters. The external projections of their retinal pictures are hence slightly distorted ellipses, of which the upper vertices are farther apart and the lower vertices nearer together than their centers. The binocular combination is hence an ellipse whose plane is oblique, the upper vertex being farther, and the lower vertex nearer to the observer. A pair of small circles below the large ones are binocularly combined with opposite obliquity.

No explanation is now needed to show that if the planes of the cards be revolved into the positions P″Q″ and P‴Q‴ (fig. 4), the combination of the concentric circles must present a concave surface and the obliquity of the plane of each pair of conjugate small circles, when binocularly viewed, must be reversed in sense.

Brewster's remark about the phantom wall that "it generally advances slowly to its new position"[10] is now easily understood. When E and E′ (fig. 2) are binocularly viewed, since EO exceeds E′O′, there must be dissociation between the two focal adjustments which are generally adapted to the same distance. To this must be added the necessary dissociation between axial and focal adjustments, the former being for an infinite distance, the latter for the distance O C, when C and C′ are binocularly viewed. To untrained eyes this unusual combination of muscular actions is at first a little confusing, and for a few seconds it is often difficult to decide whether the surface appears convex or concave. Despite this inconvenience, if the experiment be performed with axial parallelism, the image soon becomes clearly defined. With strong axial convergence, as in Brewster's method, the dissociation is far more difficult on account of the extreme muscular strain that is necessary.

By holding the cards, fig. 4, with their planes coincident and then drawing them apart in this plane, so that 6° or 7° of divergence of visual lines is necessitated in retaining retinal fusion, the image changes very perceptibly from that of a flat plate to that of a shallow concavity. By cross vision the opposite is obtained; but not so strikingly, for the muscular strain of 7° of divergence I find to be as great as that of 60° or 70° of convergence.

If vertical lines, $a\,n$, $a'n'$, fig. 5, be combined binocularly

they appear as a tangent to the curved surface, and this pierces the planes of the small ellipses, passing through each at its center. Any inaccuracy in either drawing interferes with these results and is at once manifested in the binocular picture.

40 W. 40th st., New York, Feb. 25, 1882.

REFERENCES.

[1] This Journal, Nov. and Dec., 1881.
[2] Edinburgh Transactions, vol. xv, Part III, p. 360.
[3] Brewster on the Stereoscope, London, 1856, pp. 50–100.
[4] This Journal, II, vols. xx and xxi.
[5] Am. Journal of Photography, vol. v, p. 114.
[6] Helmholtz, Optique Physiologique, p. 827.
[7] This Journal, Dec., 1881, p. 447.
[8] Optique Physiologique, p. 824.
[9] Brewster on the Stereoscope, p. 91.
[10] The same, p. 95.
[11] This Journal, II, vol. xxi, p. 181.
[12] Elementary Physiology, Macmillan & Co., p. 280.

ART. XXXII.—*On a great dyke of Foyaite or Elæolite-syenite, cutting the Hudson River Shales in Northwestern New Jersey;* by BEN. K. EMERSON.

IN the Geology of New Jersey by Professor G. H. Cook, 1868, p. 144, an extensive dyke, "on the eastern slope of the Blue Mountain," is described as follows from the manuscript notes of Mr. E. Hauesser, assistant on the earlier geological survey under Dr. Kitchell: "On the slope of the Blue Mountain between Beemersville and Libertyville, a dyke of porphyritic hypersthene rock has been intruded between the slate and conglomerate. It runs from a point one and a half miles northwest of Libertyville, without interruption, to its termination, which is one and one-fifth miles northwest of Beemersville. It is about a quarter of a mile wide, and is a little tortuous in its course, but its general bearing is northeast and southwest. The rock of the northeastern part consists usually of a coarsely granular aggregate of labradorite and hypersthene, associated occasionally with hornblende, mica, sphene, tourmaline and quartz. The labradorite occurs in imperfect crystals, and in distinctly cleavable masses; it is of a gray color and a pearly luster. The hypersthene is of a greenish black color, of a bright metallic luster; it occurs in small and slender crystals more or less perfect.

"At the southwestern extremity the dyke presents a peculiar and striking appearance. It does not occupy a long and high hill, with nearly perpendicular slopes, like the northeastern part, but, owing to a powerful and rapid disintegration, it has

crumbled into loose pieces and into a fine sand, which form a range of low hills with gentle slopes, and which, seen from a distance, look exactly like hills of sand or drift.

"The dyke here consists of a rather coarsely granular aggregate of labradorite, sphene, mica, quartz, pyroxene and iron pyrites. The sphene is of a brown to yellowish brown color, of an adamantine luster, and occurs in small, more or less perfect, crystals, in such quantity as to form one of the principal constituents of the rock.

"The iron pyrites is profusely disseminated throughout the rock, and causes the rapid decomposition.

"There is usually a marked difference between the middle of the dyke and the margins, the material being distinctly crystalline at the middle while it is compact at the surface. The dyke is traversed by joints and by some small veins, and it also sends out veins into the contiguous rocks.

"The slate has been altered for a distance of three thousand feet from the southeastern border of the dyke.

"Very near the dyke the rock is so much changed that the stratification cannot be determined, but farther off, though the rock is much changed, the marks of stratification are still plain, and the rock has the usual northwesterly dip."

Being fresh from a study of the wonderful "Cortland series," under the kind guidance of Professor Dana, my attention was immediately attracted by the description above of a great dyke of hypersthenic rock which crumbled readily into hills of coarse sand, and had exerted such powerful metamorphic influence upon the soft Hudson River rocks, and I visited the locality in the hope that it might throw some light upon the complexities of the Cortland region. Leaving the railroad at Deckertown just above Franklin Furnace, the drive of six miles was over a hilly country of soft crumbling shales. More than half a mile from the dyke its influence was manifest, the shales having changed into a dark gray compact mass, breaking into wedge-shaped pieces bounded on all sides by slickensides. Nearer at hand the shales are baked into a complete hornstone of a black color, breaking with the perfect conchoidal fracture of flint, and cut into small fragments by numerous joints. Where the road over the mountain leaves the road which skirts the mountain on the east, at the house of Mr. D. B. Roloson, this is seen in great perfection on the hillside, and in the orchard above this gentleman's house, a band of limestone occurs—a dark gray fine grained rock, which might be easily mistaken for a fine-grained diorite. It has, however, the rusty corroded surface of a siliceous limestone. Scales of biotite are disseminated in it in considerable abundance, and the rock is so rich in magnetite that the coarse powder is readily

While the calcites are limpid, the orthoclase crystals, opaque white by reflected light, are of deep reddish brown by transmitted light, and this color, which is caused by the abundance of a very fine red dust, is spread uniformly over every portion of every crystal, except in one slide where they are quite fresh, and enclose in considerable number small perfect spheres of a deep brown to black color, which seem to be some hydrocarbon compound which has been included in the forming crystal in a liquid state. This black carbonaceous matter is scattered here and there through the mass, and it is sometimes aggregated in the midst of a brownish substance in such a manner as to suggest an incipient stage in the formation of chiastolite crystals. All the rest of the micaceous ground-mass is mottled by a great number of very minute, stout, rod-like forms, four to six times longer than broad, and quite uniform in size and distribution, though not always regular in shape, being often rounded, pointed, or ravelled out at one or both ends. They are nearly opaque but resolvable (×800) in the thinnest places into a congeries of red scales. The specimen contains a single large crystal of a dark green chlorite, visible to the eye, and these minute forms may have resulted from the decomposition of a similar mineral, but it seems to be rather an early stage in the growth of some ferruginous mineral like ottrelite.

On crossing the high terrace-like buttress of thoroughly metamorphosed rocks, here, perhaps forty rods wide, one comes upon the sharp slope of the great ridge formed by the dyke itself. The contact of the dyke and the enclosing rock was nowhere to be seen. Where it was first met with in place, a little way up the slope, the foyaite bears no resemblance to the compact trap-like rock from near Roloson's, described above. It is completely granitic in texture, of medium grain, and of a grayish flesh color, deriving this color mainly from the elæolite which is its principal constituent. The latter is so abundant that a small piece of the rock treated with hydrochloric acid changed into a thick jelly, in which only a small quantity of black aegirite remained undissolved. The hand specimens which I got from this portion of the dyke contain certainly 90 per cent of elæolite. The mineral possesses the usual greasy luster, is granular massive, yet shows under the lens everywhere incomplete crystalline outlines.

The component next in importance is aegirite, which appears in black elongated crystals up to 3^{mm} in length, upon which I was able to measure the angle of the prism 92° 47′. The mineral fuses with somewhat greater difficulty than the Norwegian aegirite, and tinges the flame yellow. The surface of many of the crystals is brightly iridescent, as is sometimes the case with the arfvedsonite from Kangerdluarsuk, and the crystals

can be seen toward the surface of the rock to be changed for a part or the whole of their length into a greenish black, fibrous, hornblendic mineral apparently arfvedsonite.

The third constituent, orthoclase, occurs in elongated Carlsbad twins up to 30^{mm} in length; in a single instance three crystals are twinned together. They are of brilliant luster, and of the same flesh color as the elæolite in the fresh rock, while toward the surface they are whitened, and there closely resemble the feldspar of the Brevig zircon-syenite. They are scattered in the rock somewhat distantly, so that in three sections no feldspar appeared. The crystals enclose rounded masses of elæolite as well as crystals of ægirite, often so thickly crowded as to give the feldspar a pegmatitic appearance.

Titanite occurs in minute crystals quite abundantly. The maximum length is about 1^{mm}. It is of bright reddish yellow color, transparent, and of adamantine luster, and is always well crystallized in both complex and simple forms, with the faces often brightly iridescent. No trace of triclinic feldspar or of hypersthene could be found.

High up along the crest of the ridge, perhaps fifty rods west of the point where the specimens were obtained which furnished the material for the above description and for microscopical study, the rock is much coarser grained, more loosely granular and decomposed, falling readily to a mass of coarse grains under the hammer.

The proportion of elæolite is here much less, and the only additional mineral found in this coarser variety was a glossy black mica, which gives all the blowpipe reactions of astrophyllite, but it may be a biotite containing much manganese.

Under the microscope by far the greater portion of the section is elæolite, with scattered crystals of ægirite and titanite. The elæolite presents itself in three forms, quite distinctly demarked: (*a*) as distinct crystals, stout hexagonal prisms with end faces, of much the same appearance and properties as in the more modern nepheline rocks. These crystals are rare. The cleavage is more perfect and delicate than in the remainder of the elæolite in which they are embedded, and as a result they are only slightly decomposed. They are quite free from enclosures. The second form (*b*) appears in somewhat larger, aggregated, and more imperfect crystals, in which the basal, prismatic and pyramidal cleavages are ruder and more open, and the crystals much more decomposed. Flakes of a green hornblendic mineral, probably arfvedsonite, appear as enclosures parallel to the three cleavages. Finally it occurs (*c*) filling up the interstices of the other two forms like the quartz of a granite, and swarming with minute acicular microlites, especially in the recesses made by neighboring crystals of earlier formation. This portion has a less distinct cleavage and is less decomposed.

The freshest ægirite shows six-sided cross-sections (*l*, *i-i*,) remarkably regular both in form and cleavage, the latter being in straight equidistant lines carried generally clear across the crystal, and thus differing widely from that of augite. It is red brown with much depth of color in cross-sections, blackish brown in longitudinal plates, free from enclosures, and without trace of fibrous structure. Both in lengthwise and cross sections it absorbs the light with a single Nicol's so strongly that at the point of extinction it becomes jet black. The pleochroism is also very marked, ranging from charcoal brown to deep emerald green. In other crystals, starting from one end, the color in ordinary light changes gradually from dark brown into a bright green, and corresponding with this change of color the mineral becomes quite suddenly fibrous, and filled with minute grains of magnetite, which are wanting in the unchanged portion. The changed portion has all the microscopic peculiarities of a fibrous hornblende. In longitudinal sections of the ægirite a cleavage parallel to *O* appears, and in one instance occurred a well terminated arrow-headed twin—twinning plane *i-i*. Its crystals often radiate from or enclose a crystal of titanite.

The titanite appears in wine-yellow, limpid, much fissured, cross-sections, distinctly pleochroic, rough of surface, never sinking to the smallest dimensions, or containing any enclosures. Besides ægirite the microlites often radiate from it. Beautifully distinct twins occur with the twinning plane *O*, and with crossed Nicols the light is extinguished at 33° on either side of this plane.

Sodalite occurs rarely in wholly apolar patches irregularly bounded by the other constituents, and showing rude dodecahedral cleavage.

The order of crystallization of these minerals is interesting. The titanite is plainly the first formed, and had reached its limit before the appearance of the other constituents, except perhaps the first form (*a*) of the elæolite. These are almost without enclosures of any kind. Next the second portion of the elæolite (*b*) crystallized out, and during the time of its formation the hornblendic mineral, which is included in it in scales, as well as the ægirite which radiated from the earlier formed titanite, appeared. This green hornblendic mineral as it is synchronous with the ægirite and as it is found in the most decomposed portion of the elæolite, I take to be arfvedsonite paramorph after the ægirite.

Toward the close of this period the orthoclase, which encloses the imperfect crystals of the elæolite and the ægirite, separated out, and all these minerals share the same freedom from microlites, a great swarm of which is included in the third form of

the elæolite (*c*) which has taken its shape entirely from the preceding minerals and which thus closed the series.

Out on the plateau of metamorphic rock I picked up a curious mass not in place, which showed a contact of foyaite on foyaite of different age. The older was coarser grained than I found it elsewhere and richer in orthoclase, being largely made up of crystals 25–30^{mm} long, distributed porphyritically in a fine-grained rusty ground containing pyrite. The newer rock, resting on this, has a rudely columnar structure at right angles to the plane of contact, resembling somewhat the gypsum crusts from salt vats.

The columns of which this layer consists are elongate imperfect crystals of orthoclase and elæolite and bundles slightly radiated of a greenish black hornblendic mineral. Small tufts and spheres of the latter are also scattered through the mass, together with some dark purple fluor and much pyrite.

Under the microscope distinct crystals of elæolite appeared and the hornblende needles were contracted, like the handle of a dumb-bell as they passed through such a crystal, showing that the hornblende had here commenced its crystallization first and that the two minerals had thereafter increased together.

The hornblende crystals are now in an advanced stage of decomposition, being resolvable into an aggregate of short interrupted fibers and so impregnated with scales of "ferrite" as to be often quite opaque, and the same material has also often gathered on the needles in large masses like the warts on a plum twig. Only rarely in unchanged non-fibrous portions of green color could the angle of extinction of hornblende be measured. The feldspar was orthoclase with no indication of the presence of microcline.

The aphanitic and the granitic varieties of the rock described above are connected by intermediate grades of fine grain in which occur segregations in size and shape like a hen's egg, composed of coarse granular orthoclase, ægirite, pyrite and fluor.

Decomposition has everywhere affected the superficial portions of the dyke, and at the summit where the rock is coarsest, extended quite deeply, but without the formation of any zeolitic minerals.

Amherst College, Massachusetts, April, 1882.

ART. XXXIII.—*Notice of the remarkable Marine Fauna occupying the outer banks off the Southern Coast of New England, No. 5*; by A. E. VERRILL. (Brief Contributions to Zoology from the Museum of Yale College: No. LI.)

ANTHOZOA (*continued.*)

Pennatulacea.

PREVIOUS to 1871 no representative of the Pennatulacea had been discovered on the American coast between Cape Hatteras and the Arctic Ocean. In that year, and also in 1872, a number of specimens of *Pennatula aculeata* and of a small *Virgularia* were dredged by Mr. J. F. Whiteaves in the deeper parts of the Gulf of St. Lawrence. In 1872 these were also dredged by Dr. A. S. Packard and Mr. C. Cooke, on the "Bache," in the Gulf of Maine (see this Journ., v, pp. 5, 100, 1873). Subsequently the former species has been obtained in many localities, and in large numbers, off the coasts of New England and Nova Scotia.

Since the summer of 1878, when the Gloucester fishermen became interested in bringing home, for the use of the U. S. Fish Commission, the various objects taken on their deep-sea lines, they have not only presented large numbers of this species, from many localities, but they have contributed several others that are of still greater interest, including more than a hundred fine specimens of the very large *Pennatula borealis*, many of them nearly two feet long, with about as many of *Ballicina Finmarchica* and *Virgularia* (*Anthoptilum*) *grandiflora* V., together with a few specimens of *Funiculina armata* V. and a *Halipteris*. All these interesting additions to our fauna have already been recorded by me, in 1878 and 1879, in this Journal, in former articles of this series. All these species have also been dredged by our parties on the "Fish Hawk."

Nevertheless, in the recent work of Professor Kölliker on the Pennatulacea of the Challenger expedition,* in discussing the distribution of the group, he states that no Pennatulidæ are known on the Atlantic coast of America. This was the case eleven years ago, but the reverse has been true since that time. I have, at the present time, more than a thousand examples of our two species of *Pennatula* in my possession.

All the species will be fully described and figured, and the details of their distribution will be given, in a report on our Anthozoa, soon to be published in the report of the U. S. Fish Commission.

* The Zoology of the Voyage of H. M. S. Challenger, vol. i, Part ii, Report on the Pennatulida, by Professor Albert V. Kölliker, 1880.

Pennatula aculeata Danielssen and Koren.

Pennatula aculeata Danielssen, Forhandl. Vidensk.-Selsk. Christiania. 1858, p. 25; Fauna Littoralis Norvegiæ, iii. p. 86, pl. 11, figs. 8–9. 1877.
Verrill, this Journal, v, pp. 5, 100. 1873.
Pennatula phosphorea, var. *aculeata* Sars; Kölliker, Alcyonarien, i. Pennatuliden, p. 134, pl. 9, fig. 73, 1870.

This species is very abundant and widely distributed on our coasts, in 100 to 487 fathoms, on soft muddy bottoms. Gulf of St. Lawrence, 160–200 fathoms,—Whiteaves, 1871–3; Gulf of Maine,—U. S. Fish Commission, on the "Bache," 1872–3; Grand Bank, St. Peter's Bank, Banquereau, Western Bank and other banks off Nova Scotia, in 60 to 300 fathoms,—Gloucester fishermen (in 29 lots, including about 90 specimens); off Cape Sable, N. S., 88 fathoms,—U. S. Fish Commission; off Martha's Vineyard and Block Island, and off Chesapeake and Delaware Bays, 1880, 1881, in 100–487 fathoms,—U. S. Fish Commission. Several hundreds of specimens were taken at each of the stations 943, 945, 1025. Also taken by Mr. A. Agassiz, on the "Blake," 1880, in 197 to 524 fathoms. Chistiansund, 30–100 fathoms,—Sars and Danielssen. Eastern Atlantic, 300 fathoms,—Carpenter and Thomson.

Variety, *rosea* Danielssen, op. cit., p. 88.

Several fine specimens of this handsome variety occurred among a large number of the usual dark red variety, at stations 943, 945, 1028. It differs only in color.

Variety, *alba* Verrill.

This name is used to designate a pure white variety, which was taken at station 1025, in 216 fathoms.

Pennatula (Ptilella) borealis Sars, sp.

Pennatula grandis Ehrenberg, Corall. rothen Meeres, p. 66, 1832, (*non* Pallas).
Kölliker, Zool. Voy. Challenger, i, pt. ii, p. 4, 1881.
Pennatula borealis Sars, Fauna Lit. Norvegiæ, i, p. 17, pl. 2, figs. 1–4, 1856.
Kölliker, Pennatuliden, i, p. 136.
Verrill, this Journal, xvi, p. 375, 1878.
Ptilella borealis Gray, Catalogue of Sea Pens, p. 21.
Verrill, this Journal, xvii, p. 241, 1879.
Ptilella grandis Koren and Danielssen, Fauna Lit. Norvegiæ, p. 82, pl. 11, figs. 1–7, 1877.

One young specimen of this magnificent species was dredged by us at station 925, in 224 fathoms. From the Gloucester fishermen over 120 specimens, mostly of large size, have been received by the U. S. Fish Commission, all of which have been examined by me. These were received in 83 lots, from 1878 to 1881. They were taken in 120 to 350 fathoms, on the outer slopes of the Grand Bank, St. Peter's Bank, Western Bank, Banquereau, Sable Island Bank, Le Have Bank and George's

Bank. Previously it was known from only a few Norwegian specimens, from Chistiansund, Bergensfjord, Lofoten, Banenfjord, etc., in 150 to 200 fathoms.

Balticina Finmarchica (Sars) Gray.

Virgularia finmarchica M. Sars, Fauna Lit. Norvegiæ, ii. p. 68, pl. 11.
Balticina finmarchica Gray, Catalogue of Sea Pens, p. 13.
Verrill, this Journal, xvi, p. 375, 1878.
Stylatula finmarchica Richiardi, Monografia della Fam. Pennatularii, p. 69. 1869.
Pavonaria finmarchica Kölliker, Pennatuliden, p. 243. 1871 (*non Pavonaria* Cuvier).

Several specimens were trawled by us, off Martha's Vineyard, in 160 to 238 fathoms, in 1880 and 1881. The Gloucester fishermen have presented many large and fine specimens (more than 75), some of them over two feet long. These came in 57 lots, from the outer slopes of the Grand Bank and all the banks off the Nova Scotia coast, in 60 to 400 fathoms. Off George's Bank, 980 fathoms.—A. Agassiz, 1880. It was previously known off Finmark, 240 fathoms; Bergenfjord, 300 fathoms.

While a majority of these specimens are large and perfect, some examples of this, and other related species, have more or less of the distal portion of the axis bare, and sometimes bare or partially bare portions of the axis are seen along the middle region; not rarely, as much as one-half of the whole length is bare. This, I am convinced, is entirely due to accidental injuries received while still living.* In most cases the bare portions of the axis, whether terminal or median, have one or two, and often several, actinians firmly attached to them. The most common of these is a verrucose *Urticina* (probably the young of *U. longicornis* V.), which closely clasps the axis with its basal membrane, the edges of which unite firmly together by a suture, where they meet, thus surrounding the axis like a sheath. But other species of actinians also occur upon them, in the same way, and also hydroids, bryozoa, sponges, etc.

The very young specimens of this species have the polyps isolated, thus forming two simple alternate rows, along the rachis. These agree essentially with the genus *Microptilum* Kölliker (Challenger Voyage. Pennatulida, page 26). Indeed, I am convinced, after examining the young of several genera of Virgularidæ, that the several genera proposed by Kölliker for the small forms, with polyps in two simple rows, and for which he has proposed the families Protocaulidæ and Protopti-

* Koren and Danielssen mention the same peculiarity as occurring in all their specimens of *Virgularia affinis* and other European species. But they seem to think that this is a normal feature. They correctly object to the view that it is due to contraction in alcohol. (Fauna Lit. Norvegiæ, iii. p. 91).

lidæ (op. cit., p. 26), are mostly, if not all, the young of larger and more complex forms.*

Anthoptilum grandiflorum Verrill.

Virgularia grandiflora Verrill, this Journal, xvii, p. 239, March, 1879.
Anthoptilum Thomsoni Kölliker, Zool. Voy. Challenger, Pennatulida, p. 13, pl. 5, figs. 16–18, 1881.

The new genus, *Anthoptilum*, has been constituted, for species allied to this, by Professor Kölliker, (Voyage of the Challenger, Pennatulida, p. 13, 1881). He described, from a single specimen, a species (*A. Murrayi*, pl. 6, figs. 19–21) taken off Halifax, in 1250 fathoms, which is smaller and more slender than my species, with fewer polyps and larger zooids, but it may possibly prove to be the young form. From off Buenos Ayres, in 600 fathoms, he described *A. Thomsoni*, which is a large species, apparently identical, in all respects, with my species, from off Nova Scotia and New England.

We trawled this species, off Martha's Vineyard, in 302 to 310 fathoms. Its color, in life, is usually deep salmon-brown, but varies to pale salmon, and even to yellowish white. The Gloucester fishermen have presented about forty specimens, in twenty lots. These are from near the Grand Bank, St. Peter's Bank, Western Bank, Banquereau, Sable I. Bank, and Le Have Bank, in 85 to 300 fathoms. Off C. Fear, S. C., 647 fathoms,—A. Agassiz.

Funiculina armata Verrill.

This Journal, vol. xvii, p. 240, March, 1879.

Two excellent specimens of this fine species were taken at Stations 880 and 881, in 252 and 325 fathoms These were larger and more developed than the original specimen, which was taken off Sable I., N. S., in 300 to 400 fathoms.

In our largest examples the polyps are arranged in oblique rows of two to four, and the zooids, which are comparatively large, are scattered along the median ventral surface, and between the transverse rows of polyps. The polyps are deep purple; the zooids are pale yellowish, with stripes of purple.

* The genus *Protoptilum* Köll., I regard as the young of *Virgularia*. His *P. aberrans* and two other similar forms, taken off New York, in 1240 to 1700 fathoms, are apparently the same as some that we have dredged in shallower water, but among our specimens, some of the larger ones have the polyps in distinct groups of two or three; these are evidently the young of a *Virgularia*. We may, for the present, designate this form as *V. aberrans*, but it may be identical with some previously known form. The genus *Trichoptilum* Kölliker (op. cit., p. 29), I consider the young of *Funiculina*. The only species, *T. brunneum*, from off Ceram, very closely resembles the young of my *F. armata*, and I should, therefore, prefer to name it *Funiculina brunnea*. *Protoraubon* may, likewise, prove to be the young of *Anthoptilum*.

Madreporaria.

Flabellum Goodei **Verrill.**

This Journal, xvi, p. 377, 1878.

This species is very closely allied to *F. alabastrum* Moseley,* taken by the Challenger, off the Azores, in 1000 fathoms. The two forms may eventually prove to be identical, when directly compared, but none of the numerous specimens examined by me agree precisely with those described and figured by Moseley. His specimens have the calicles more oblong, with the ends obtuse, instead of acute, and the costæ are much larger, more prominent and angular; and the whole surface is rougher.

This very fragile coral has the power of restoring itself from mere fragments. Many pieces have been found showing new calicles, in all stages of progress, arising from the inner surface of the fragments of old calicles. Specimens thus restored are often irregular in form till of considerable size, and one, about an inch across, still had a nearly circular outline.

In life the color of the disk and tentacles is rich salmon; lips darker salmon, with stripes of dark purplish brown, or sometimes uniform madder-brown. The larger tentacles are stout, tapered, subacute. Our largest examples are from off Chesapeake Bay, in 300 fathoms; these are 80^{mm} high; greater diameter, 120^{mm}; lesser, 43^{mm}. A specimen from station 1029, 458 fathoms, is 65^{mm} high, greater diameter 98^{mm}, lesser diameter, 50^{mm}.

The Gloucester fishermen have presented it in eleven lots, mostly from near the Grand Bank, Banquereau, Sable Island Bank, and east of George's Bank, in 180 to 400 fathoms. We have dredged it, on the Fish Hawk, at various localities off Martha's Vineyard and Nantucket, in 219 to 487 fathoms; off Chesapeake Bay.—Captain Tanner. Large numbers were taken at stations 893–895, 925, 951, 952, but they were mostly crushed to small fragments by the great quantities of larger animals in the trawl.

Bathyactis symmetrica **Moseley.**

Fungia symmetrica Pourtales, Deep Sea Corals, p. 46, pl. 7, figs. 5, 6.

Bathyactis symmetrica Moseley, Zool. Voy. Challenger, part vii, p. 186, pl. 11, figs. 1–13, 1*a*–13*a*. 1881.

? *Fungiacyathus fragilis* M. Sars, in S. O. Sars. Remarkable Forms of Animal Life, i, p. 58, pl. 5, figs. 24–32. 1872.

Numerous broken specimens of this very fragile coral were dredged at stations 879, 880, 895, in 225–252 fathoms, 1880. Some of these specimens must have been at least 20^{mm} in

*Proc. Royal Soc., 1876, p. 555; and Zoology Voyage Challenger, Part vii, Rep. on Corals, p. 169, pl. 7, figs 1–2*b*, pl. 16, fig. 11, 1881.

diameter. They agree in all respects with the larger specimens figured by Moseley.

This coral is remarkable for having a wider range in depth and geographically than any other known species. It was taken by Pourtales, off Florida. By the Challenger it was taken in the N. Atlantic, off the Azores and off Bermuda, in 32 to 1075 fathoms; in the S. Atlantic, in 1900 to 2650 fathoms; in the South Indian Ocean, in 1600 to 1950 fathoms: in the Malay Archipelago and West Pacific, in 360 to 2440 fathoms: east of Japan, in 2300 to 2900 fathoms; off Valparaiso, in 1375 fathoms.

The *Fungiacyathus fragilis* of Sars closely resembles this coral, but its septa are not united into groups, nor are there any transverse dissepiments nor trabiculæ in the four specimens described, although some of them were larger than many of the specimens of *Bathyactis*, in which these characters are well marked. A larger series of the arctic form may, however, serve to unite them.

Actinaria.

Adamsia sociabilis Verrill, this vol., p. 225.

This starts upon a small shell, usually a pteropod (*Cavolina*), occupied by the crab, but eventually secretes a chitinous pelicle and absorbs the shell. The base becomes much expanded and bilobed, the lobes often surrounding the aperture of the shell, and uniting. Column slender and long in full expansion, very changeable, smooth, with pores near the base; disk a little wider; tentacles small, slender, in two circles, alternately erect and recurved. Mouth often protruded.

Sagartia abyssicola Verrill.

? *Phellia abyssicola* Koren and Dan., Fauna Lit., Norvegiæ, iii, p. 78, pl. 9, figs. 3, 4, 1877.

Base broad, adherent, expanded and thin at the edges, often clasping the tubes of *Hyalinœcia*, stems of *Acanella*, etc. Column narrow in the middle, expanded at summit, usually covered, except near summit, with a closely adherent coating of sand, foraminifera, etc., but many specimens are entirely naked. Tentacles rather slender, acute, forming about three marginal circles, more than half as long as the diameter of disk. Column flesh-color; tentacles sometimes pale flesh-color, sometimes salmon, frequently dark purplish brown, in the paler examples often with a darker streak on each side of the base; flake-white patches often occur between their bases, or at the margin; disk usually orange-brown or purplish brown, with lighter and darker radii. Pink acontia are often emitted abundantly from pores scattered on the column, and from the mouth.

Very abundant in this region, in many localities, on pebbles, shells, worm-tubes, *Acanella*, etc.; 76–506 fathoms.

List of Anthozoa.

PENNATULA ACULEATA Kor. & Dan. 100 to 487 fathoms.

S. 869, 873, 875, 878 ab., 880, 892, 895 ab.: 897: 924, 925, 938, 943 ab., 945 very ab., 946 ab., 951, 999, 1025 very ab., 1026 ab., 1028, 1029, 1032, 1045.

PENNATULA ACULEATA, var. ROSEA Kor. & Dan. S. 943, 945, 1028.

PENNATULA ACULEATA, var. ALBA Verrill. 216 fathoms. S. 1025.

PENNATULA (PTILELLA) BOREALIS Sars. 224 fathoms. S. 925 l j.

BALTICINA FINMARCHICA Gray. 160 to 238 fathoms.

S. 895: 924, 925, 945, 951.

VIRGULARIA, sp. (young). 487 fathoms. S. 892.

ANTHOPTILUM GRANDIFLORUM V. [=VIRGULARIA GRANDIFLORA V.] 302 to 310 fath. S. 938, 998.

FUNICULINA ARMATA Verrill. 252 to 325 fathoms. S. 880, 881.

ACANELLA NORMANI Verrill. 219 to 458 fathoms.

S. 880, 881 ab., 893 ab., 894, 895: 937, 938 very ab., 947 very ab., 951, 1028, 1029 very ab., 1031.

ANTHOTHELA GRANDIFLORA (Sars) V. 255 fathoms. S. 1031.

ANTHOMASTUS GRANDIFLORUS Verrill. 410–458 fathoms. S. 1028. lj., 1029 ab.

ALCYONIUM CARNEUM L. Agassiz. 8 to 30 fathoms.

ADAMSIA SOCIABILIS Verrill, sp. nov. 86 to 410 fathoms.

S. 869, 870–873, 875–878: 898: 923, 940–941 very ab., 1027 ab., 1028, 1035 ab., 1036 ab.: 1043.

SAGARTIA ABYSSICOLA (Kor. & Dan.) V. 76 to 506 fathoms.

S. 869, 873, 880, 892, 895, 894: 897: 923–925 ab., 937–939, 940 ab., 941, 949, 951, 1025, 1028, 1032 ab., 1033, 1038 ab., 1039: 1043, 1047.

URTICINA (TEALIA) CRASSICORNIS Ehr. 16 to 40 fathoms.

URTICINA CRASSICORNIS Ehr. (?) Young. 86 to 146 fathoms.

S. 872 ab.: 923, 949 ab., 1038 ab., 1039, 1043.

URTICINA (TEALIA) LONGICORNIS Verrill. 120 to 325 fathoms.

S. 869, 876, 877, 879–881: 924, 938, 945, 1032, 1033, 1043.

URTICINA LONGICORNIS V. (?) Young.

S. 924, 925, 945, 951. On *Balticina.*

URTICINA (TEALIA) PERDIX Verrill, sp. nov. 61 to 115 fathoms.

S. 871, 872: 920, sev. l., 921, 922.

URTICINA (TEALIA) NODOSA (Fabr.) Verrill. 100 to 506 fathoms.

S. 869, 872, 876–881, 893–895, 898: 924 ab., 925, 937 939 ab. l., 945, 949, 951, 997, 998 ab., 1025, 1026, 1028, 1029, 1031–1033, 1038, l.

URTICINA CALLOSA Verrill, sp. nov. 120 to 335 fathoms.

S. 876, 879–880 ab. l., 894: 924, 946, 951, 997, 998, 1025, 1031, 1033.

URTICINA CONSORS Verrill, sp. nov. 160 to 458 fathoms.

S. 924, 938, 939 (3), 947, 1029.

ACTINERNUS SAGINATUS Verrill, sp. nov. 458 fathoms. S. 1029.

BOLOCERA TUEDLÆ Gosse. 65 to 365 fathoms.

S. 879–880 ab., 894, 895: 921, 924 ab., 925 l., 938–939 ab. l., 1031–1033.

CERIANTHUS BOREALIS Verrill. 100 to 258 fathoms.
S. 873, 875, 876, 878, 897: 939.

EDWARDSIA FARINACEA Verrill. S. 1038.

EPIZOANTHUS AMERICANUS Verrill. 28 to 487 fathoms.
S. 865, 869–878 very ab., 880, 892, 894, 895, 896: 898 ab., 899: 918–924 very ab., 939, 940 ab., 941, 944 very ab., 945 ab., 949 ab., 985–990, 997–999, 1025, 1027, 1032 ab., 1035 ab., 1036 very ab., 1038, 1039, 1040, 1043, 1046.

EPIZOANTHUS AMERICANUS V., encrusting variety (=*Zoanthus Norvegicus* Koren & Dan.) 69–160 fathoms.
S. 871–873 ab.: 922–924, 940 ab., 941. 949, 1036, 1038 ab., 1039, 1040, 1043, 1046.

EPIZOANTHUS PAGURIPHILA Verrill, sp. nov. 252 to 458 fathoms.
S. 880, 883, 893, 894: 938, 947 very ab., 994, 997, 998, 1028, 1029.

PARACYATHUS, sp. 65 fathoms, on shells. S. 865.

FLABELLUM GOODEI Verrill. 219 to 487 fathoms.
S. 879, 880, 892, 893–895 ab., 898, 3 l.: 925 ab., 938, 946, 951 ab.. 952 ab., 1028, 1029, 1031.

BATHYACTIS SYMMETRICA Moseley. 225 to 252 fathoms. S. 879, 880, 895.

PARASMILIA LYMANI Pourt. 57 to 130 fathoms. S. 899 ab.: 940 ab., 949, 1040.

ART. XXXIV.—*On the Determination of Phosphorus in Iron;* by J. LAWRENCE SMITH, Louisville, Ky.

IN recent years it has been a matter of considerable interest to determine the amount of phosphorus in the iron used in the arts, especially in that form of it known as pig iron; in fact, since the manufacture of steel by the process of conversion known as the Bessemer process, it has become a necessary procedure to ascertain the peculiar fitness of the cast-iron for this purpose; and has a bearing also upon the commercial value of pig-iron. It is not many years ago that a few thousandths in the difference in the amount of phosphorus in two lots of pig-iron had but little effect upon its commercial value, while now, its presence affects it to the extent of several dollars value per ton.

Formerly but little reliance was to be placed upon the analytical estimate of the amount of these small percentages of phosphorus in iron, and uniform results were not furnished by different analysts. It was not until the use of an acid solution of molybdate of ammonia* was employed, that reliable results were to be had. Many years previous (in 1852), when I established the constant presence of phosphorus in meteoric iron, I was obliged to devise a process which, while it gave very good results, was not applicable to the present use.

The so-called molybdic acid process did not at first satisfy

* Method of making described in Fresenius's Analytical Chemistry.

all chemists, and in hands of all did not give the uniform results desired, and even at the present time, modifications are constantly being sought after.

The molybdic acid process, as first used, was to precipitate the phosphorus from a nitric acid solution of the iron by an acid solution of the molybdate of ammonia, redissolve the molybdate of ammonia in ammonia, and precipitate the phosphorus by chloride of magnesia and ammonia, and estimate the amount of phosphorus from the phosphate of magnesia.

The reasons for not estimating the phosphorus by the first molybdate precipitate were, first, the supposed indefinite nature of the precipitate, and secondly, the occasional presence of free molybdic acid in the precipitate; it was also recognized that the large amount of iron in the solution interfered materially with the precipitation of all the phosphorus, and it was made very apparent that the phosphorus must be concentrated into a small portion of the iron before commencing the process of analysis.

With these facts well established to my mind, I have been engaged off and on for two or three years examining the question of the determination of phosphorus in iron and steel, making several hundreds of variously modified experiments, and repeating the details of processes adopted by different chemists.

I first tried the solution of from one to three grams of iron or steel in aqua regia, and precipitating by the molybdic solution, with all the iron present and without separating the silica; but the process gave no satisfaction, whatever way the phosphorus was ultimately weighed; nor did the evaporation to dryness over a water-bath and redissolving with a little nitric acid materially improve it. It became very evident, as already recognized by several English and American chemists, that silica must not be in the solution in which the molybdic precipitate was made; and, furthermore, that the larger portion of iron must be eliminated from the solution before this precipitation was attempted. The chemist of the Burdon Iron Works, Troy, and of the Pennsylvania Central Railroad gave me their experience on the subject.

In describing the following method, ultimately adopted as affording the most speedy and accurate results, I give but little else than slight modifications of methods already employed by others, with such detail of manipulation as facilitates uniform method of operation.*

Quantity of iron employed.—It is customary to employ 1 gram for pig-iron, and 2 to 3 grams for malleable iron and steel: but in my own practice I employ but 1 gram for

* S. Peters has used a process nearly the same as the Burdon Iron Works, Troy.

all varieties of iron; for even where the iron or steel contains one-thousandth and less of phosphorus, I get as satisfactory results as where 2 and 3 grams are employed.

Solution.—The iron, say 1 gram, is placed in a porcelain capsule of about from 100 to 150 c. m., and 3 or 4 c. m. of water added; the capsule is placed on a water-bath, and 10 to 15 c. m. of aqua regia is added little by little; the aqua regia is prepared in advance in the usual way with two parts chlorhydric acid and one part nitric acid. The contents of the capsule are now evaporated to dryness over the water bath or more speedily on an iron plate; the capsule with its contents is then placed in an air-bath and heated from 140° to 150° C. for from 30 minutes to 1 hour—thus rendering all the silica insoluble; 3 or 4 c. m. of chlorhydric acid with an equal quantity of water are added to the dry residue, and then warmed gently over a water bath or lamp; the iron is redissolved, a little more water added, the solution filtered with the filter pump; the filtrate placed on a narrow graduated measure of 100 c. m. capacity and sufficient water added to make the liquid contents 100 c. m.; the whole is well shaken to make the solution uniform. The next step is to concentrate all the phosphorus into a limited amount of the iron.

Concentration of the phosphorus.—From 90 to 92 c. m. of the last solution is placed in a capsule of 300 or 400 c. m. capacity, either of porcelain or platinum—the latter I use by preference—and 100 c. m. of water added; the iron oxide is now reduced to iron protoxide by soda sulphite or ammonia sulphite.* I prefer the latter, and prepare it in the manner mentioned in the note; the ammonia sulphite I used at the suggestion of Mr. S. Peters, which he stated to me was used advantageously by himself and others. Two or three centimeters of the ammonia sulphite is added to the iron solution and the contents of the capsule are *boiled until all the sulphurous acid is driven off*, this stage of the process being recognized by the sense of smell. By putting a small drop of the solution on the end of a glass stirrer into a weak ammonia solution we readily recognize the complete conversion of the oxide, for the precipitate is nearly white. Of course during the whole of the above process the solution is acid, with the excess of chlorhydric acid. Ammonia is now added slowly to the warm solution until a little of the greenish precipitate remains undissolved; about 20 c. m. of acetic acid is now added to the solution (which immediately redissolves the precipitate), and then

* Equal parts of ammonia and water are placed in a bottle and an excess of sulphuric acid passed through; the operation lasts for several hours, using a mixture of charcoal and sulphuric acid. Once prepared it keeps very well. when kept from the light.

1 or 2 c. m. of ammonia acetate solution; finally, the 8 or 10 c. m. of original solution remaining in the graduated glass is added with 200 or 300 c. m. of water.

The whole contents of the large capsule is boiled gently from one-half to one hour, and if necessary the water renewed as it is evaporated. The result is the formation of a basic per-salt of iron containing practically all the phosphorus that was originally in the gram of iron used.

Separation of the phosphorus from the above precipitate.—With a filter-pump on a 3½-inch filter, the last precipitate is collected in 15 or 20 minutes; the precipitate is not washed, but a mixture of 5 or 6 c. m. of chlorhydric acid, with an equal quantity of water, is warmed in the capsule in which the boiling has taken place, so as to dissolve the adhering oxide of iron; the hot acid solution is thrown on the filter in the funnel, detached from the pump, the filtrate is readily dissolved and passes in some convenient vessel, and the filter washed once or twice; this solution is placed in a porcelain capsule and evaporated to dryness over a water-bath or on a hot plate. I prefer the former, although it takes a longer time. To the dry, but not over-heated residue is added 1 to 2 c. m. of nitric acid, with an equal quantity of water; this will furnish a clear solution if there be no titanium in the iron; if the latter be present, there will be formed a flocculent precipitate that can be readily separated by a filter prior to the last treatment.

The last treatment.—The solution now need not be more than 10 or 20 c. m., to which ammonia is to be added until the precipitate first formed is no longer redissolved; then add a few drops of nitric acid to clear up the solution completely, in which the phosphorus is supposed to have been concentrated. 30 c. m. of molybdic acid solution is now added to the last solution in a small beaker which is then warmed for 15 or 20 minutes to a temperature of 80° C., and agitated with a glass rod. The phosphorus is precipitated as the double ammonia-salt, and settles as a chrome-yellow powder in less than 30 minutes, and is ready for collection on a double filter,* although I commonly allow two hours or more time to elapse before filtering and washing with the filter-pump. As the filter is very small it is readily washed with a little distilled water.

* Whenever I filter a participate to be weighed on the filter, a double filter is used, each of the same size; they are weighed one against the other and exactly balanced by the weights; on the lighter one a + mark is put with pencil, and the number of mg. that it is lighter than the other. As only a 2½ or 3-inch filter is used, the difference in weight between the filters does not usually exceed 10 or 20 mg. I always keep a number of these double filters (with the difference marked on them) ready for this purpose or any other.

After washing, the double filter is placed in an air-bath heated to about 120° C., and in about 30 minutes weighted by separating the filters, the complete dryness is verified by a second heating in the air bath.

Of the phospho-molybdate every 100 m. g. will contain 1·63 m. g. of phosphorus, or 3·74 m. g. of phosphoric acid. The result of this method of analysis will indicate a very minute quantity of phosphorus less than what is contained in the iron, but so small as not to affect the practical result, and will be more accurate, certain and speedy than if estimated as magnesian phosphate.

Cold short iron.—It has been customary to attribute the cold shortness of certain iron to the presence of phosphorus. Now, after working on this problem in rolling mills, I have found that the phosphorus cannot alone account for this peculiarity. Very often I have taken a 1-inch and $1\frac{1}{2}$-inch iron that was very cold short and working them down to smaller sizes, as $\frac{1}{2}$-inch bars, etc., found that very good merchantable iron is produced, capable of being bent and forged cold or hot as well as any good quality of iron, although the phosphorus in the large and small iron is the same in quantity. I would not say that phosphorus has no effect on the cold shortness of iron, but I would remark that whatever effect it has is very much modified by the manner of working the iron. And this opinion is sustained by that of others who have had much to do with the working of iron.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Apparatus for illustrating the action of Geysers.*—In J. Müller's Cosmical Physics, 2d ed., p. 386, 1865, Bunsen's theory of the eruption of geysers is illustrated by filling a vertical metallic pipe with water and applying heat to its middle portion and to its lower end. G. Wiedemann believes that this apparatus does not truly represent the actual phenomenon, since it is hard to conceive of the earth's heat being applied in two points; and he has for several years used the following apparatus in his lectures. A Florence flask is provided with a long vertical glass tube drawn out at its upper end into a comparatively small orifice. Another glass tube passes through the cork which closes the mouth of the flask and is led away at an angle to a glass bottle which it enters by a stop cock at the base of this bottle. This bottle is filled with water, the height of the liquid being about at the level of the top of the vertical glass tube which rises from the Florence

flask. The Florence flask filled with water is heated from beneath by a Bunsen burner, and water entering through the stop cock from the glass bottle is raised to the boiling point. The bubbles of steam rise in the vertical tube and the alternations of heating in the flask and changes of level of the water in the vertical tube cause steam and water to issue with violence from the vertical tube. The tube conveying the cold water to the Florence flask should be curved at its lower end to prevent the cold water from striking the hot base of the flask, and the vertical tube should be flush with the bottom of the cork which closes the Florence flask.—*Ann. der Physik und Chemie*, No. 1, 1882, pp. 173–175. J. T.

2. *Electrical resistance of Gases.* — E. Edlund in this paper reviews the results of previous experimenters, especially those of Becquerel and Hittorf. Since it is known that gases differ from solid and fluid bodies in not conducting electricity until the electromotive force acting upon them has reached a certain limit, Edlund shows that the strength of the currents passing through layers of gases cannot be inversely as the resistance of these layers. Becquerel and Hittorf's experiments, however, lead to this erroneous conclusion. Edlund shows that his unitarian theory of electricity is borne out by the behavior of gas in respect to electrical conduction.—*Ann. der Physik und Chemie*, No. 1, 1882, pp. 165–171. J. T.

3. *Dielectric polarization in Electrolytes.* — The phenomenon of electrical conduction through electrolytes has lately been the subject of much investigation, and R. Colley in 1879 stated his conviction that each electrode immersed in the electrolyte acted, with its layers of gases, as a condenser and the intervening liquid as a conductor. Helmholtz in the same year showed that the electrodes placed very near each other acted as a condenser intercalated in a circuit. R. Colley has returned to the question and has investigated the action of a series of substances which pass by degrees from the condition of conductors to indifferent conductors of electricity. Among these substances were benzol, light benzine, heavy benzine, petroleum, olive oil, solution of chloride of iron in benzol, and ether. The results of his investigation confirm the views of Faraday and Maxwell in regard to electrical action in a dielectric. Dielectric polarization exists not only in insulators but also in conductors, and the dielectric constants of electrolytes are of the same order of greatness as those of true dielectrics.—*Ann. der Physik und Chemie*, No. 1, 1882, pp. 94–111. J. T.

4. *Change of temperature due to extension and contraction of metallic wires.*—In works on thermo-dynamics the expression $\vartheta = -\frac{(273+t)\,\alpha P}{A \cdot w \cdot c}$ is given for the change of temperature which results from mechanical strains in wires produced by extension and subsequent contraction. In this expression,

A is the mechanical equivalent of heat,
P the change of tension,
α the coefficient of expansion,
C the specific heat,
W the weight of unit length.

Joule was the first to test the formula and his results did not entirely confirm the theoretical result. Edlund found that the formula led to a value of A=682·7 kilogrammeters, and concludes that the discrepancy must be explained by the presence of internal work in the wire. Rühlman is opposed to the conclusion of Edlund, and does not think it probable that the specific heats of stretched wires can differ essentially from those of unstretched wires. H. Haga has accordingly tested the formula experimentally, measuring carefully the specific heats of the wires. From a steel wire and a German silver wire the values of A were 437·8 and 428·1 respectively, and the author therefore concludes that the formula is correct and the mechanical theory of heat explains the changes of temperature which follow the extension and contraction of wires.—*Ann. der Physik und Chemie*, No. 1, 1882, pp. 1–18. J. T.

5. *Phosphorescence.*—Capt. Abney, R.E., at a meeting of the Physical Society, London, Jan. 28, exhibited some experiments upon phosphorescence, and showed that a surface covered with Balmain's luminous paint, which is violet when excited by daylight, becomes more violet when it receives the blue rays of the solar spectrum. The red end of the spectrum, however, extinguished the violet phosphorescence. The light of an electric lamp passed through a sheet of red glass also extinguished the phosphorescence. Capt. Abney believes that there are a series of octaves in the blue end of the spectrum which do not extinguish the violet light. The mean wave length of the rays exciting the phosphorescence was found to be 4300.—*Nature*, Feb. 9, 1882. J. T.

6. *Discussion of the Fourier-Poisson theory of the conduction of heat.*—The principal objections to this theory are the following: 1. It does not take into consideration changes in specific heat. 2. It considers that the conductivity of a metal is independent of its expansion. 3. It considers the exchange of heat between two contiguous bodies proportional to the difference between the temperatures U and U′ of their boundaries. W. Hergesell discusses these objections and thinks that the objections 1 and 3 are not important, and that the points can be embraced by the theory. He shows, in the case of 2, that Fourier's theory demands that if the conductivity is diminished by extension that the flow of heat between like particles is increased (under certain limitations).—*Ann. der Physik und Chemie*, No. 1, 1882, pp. 19–38. J. T.

7. *Spectroscopic observations with monochromatic light.*—M. Zenger finds that benzine and benzylene in a compound prism together with quartz at an angle of 75° eliminate the extreme red, while pure anethol at the refracting angle of 75° eliminates

the extreme violet. A compound prism or parallelopiped thus formed affords the best means of studying solar protuberances and spots and the reversed lines of the chromosphere. The prism is recommended to the Transit of Venus Commission, since clearness of definition can be obtained under great dispersive and large magnifying power. It also obviates confusion arising from interference bands at the edge of the disk of Venus and the effects of irradiation are obviated. It is also claimed that better solar photographs can be obtained by the use of this prism.—*Comptes Rendus*, Jan. 23, 1882, pp. 155–157. J. T.

8. *On crystals of Potassium Chloride found in the extract of Wormwood or Absinth* (*Artemisia Absinthium* L.; by E. Claassen. (Communicated).—Some time ago I had occasion to make use of the above named extract and was surprised to find in it many perfectly transparent, yellowish, almost colorless crystals of great regularity of form. The largest were about ¼ inch in diameter and weighed 130 milligrams (about two grains). By studying their crystallographic form I found that they belonged to the isometric system; one crystal was a cube with the angles slightly replaced with octahedral planes, the others were combinations of the octahedron and cube, with either a predominant octahedron or with no predominance of either of the forms. Several of the last mentioned crystals show, however, also very nicely and distinctly besides these forms, the icositetrahedron 2-2 (202). By chemical analysis it was found, that the crystals were potassium chloride.

This salt is commonly found in cubes, and the uncommon forms described are perhaps due to the presence of organic substances in the wormwood extract.

Cleveland, Jan., 1882.

II. Geology and Mineralogy.

1. *Tides in early Geological time.*—Mr. G. H. Darwin, whose paper on the "Precession of a Viscous Solid" (Phil. Trans., 1879), called out the remarks of Mr. Ball, Astronomer Royal of Ireland, on great tides as a geological agency in early time, states, in Nature for January 5th, his non-concurrence with Mr. Ball in his conclusions. The enormous tides referred to by Mr. Ball, he would locate in pre-geological periods. He had contemplated the possibility of tides two or three times as high as at present in the earliest geological time, and observes that this estimate is probably rather excessive than deficient. As in his former paper, Mr. Darwin states that an increase of rain-fall would be an undoubted result of the conditions, and that this should have had its geological effects. When the tide was 648 feet high the moon was about ten earth's diameters distant, and, Mr. Darwin observes, the earth must have been rotating in about seven hours; the trades would probably have had a velocity of 3¾ their present velocity, and, consequently, vortical storms would have had pro-

digious violence; but these conditions would have favored the making of a large proportion of very coarse-grained sedimentary rocks, contrary to the fact among the earliest of fossiliferous strata.

Tides having twice the height of modern tides (such as existed when the moon was a fifth nearer the earth than now) would have aided much in degradation during Archæan times, by increasing the vertical range of wave and current action and the working force of tidal currents flowing through shallow seas or channels; and this action together with that of erosion resulting from large precipitation, are the chief geological effects over the earth's surface which Mr. Darwin attributes to the cause mentioned. Geologists have here no reason to question Mr. Darwin's judgment. Another effect is also mentioned in the original paper, and referred to here again: that "the ellipticity of figure of the earth must have been continually diminishing, and thus the polar regions must have been ever rising and the equatorial ones falling; but as the ocean always followed these changes, they might quite well have left no geological traces."

2. *Contributions to the History of the Vertebrata for the Lower Eocene of Wyoming and New Mexico, made during* 1881; by E. D. Cope. Read before the Amer. Phil. Soc., Dec. 16, 1881. Cope's Palæontological Bulletin, No. 34.—This paper by Professor Cope treats especially of the Lower Eocene of the basin of the Big Horn River. The upper drainage basin of the Big Horn River, which was examined in 1859 by Dr. Hayden and then pronounced Lower Eocene, was explored in 1880 by a party under J. L. Wortman, sent out by Professor Cope. From the specimens collected, Professor Cope confirms the results of Hayden's survey, concluding that the beds are intermediate between the Bridger and Wasatch beds, they containing genera hitherto regarded as peculiar to each. A lower basin lies on the same river north of the Big Horn Mountains. In 1881, Mr. Wortman, under the same auspices, made further explorations of the region, and obtained numerous extinct vertebrates from the Lower Eocene horizon. These Eocene beds "cannot be less than 4000 feet in vertical depth;" they are now eroded in bad-land style and are under bad-land dryness and other features. They consist of variously colored clays, a large part red, alternating with brown and blue sandstone layers. The species of vertebrate fossils mentioned include fishes, reptiles and mammals. Among the last, twenty-four are described as new species, and some of these are referred to new genera, and they are stated to represent fully the Wasatch fauna with little admixture of earlier or later forms. In place of the characteristic Middle Eocene (Bridger) genera, *Hyrachyus*, *Palæosyops*, *Uintatherium* and the *Tillodonta*, there are *Phenacodus*, *Hyracotherium*, *Coryphodon* and *Teniodonta*, as in New Mexico; but several genera are, as elsewhere, common to the two horizons, and two species from both, *Hyopsodus paulus* and *H. vicarius*, cannot be distinguished by the parts preserved. The

Big Horn collection is peculiar among those of Wasatch age, in the presence of numerous species of *Phenacodus* and of new and rare species of genera of *Coryphodontida*. The new Coryphodonts here described are *Manteodon subquadratus*, *Ectacodon cinctus*, *Coryphodon anax*, *C. repandus*, *C. curvicristis*, *C. marginatus*, *Metalophodon testis*; and besides these, four previously described species occur among the fossils, *C. cuspidatus*, *C. latipes*, *C. simus* and *C. elephantopus*. The collections include the new Artiodactyles, *Mioclænus brachystomus* and *M. etsagicus*, species of the oldest type of Artiodactyle yet described. The first of these species was about the size of the Javan Musk-deer *Tragulus Javanicus*. The characters of the genus are, in general, similar to those of *Dichobune*, even to the presence of the external digits (which are wanting in the Anoplotheriidæ); it differs "in the presence of but one internal tubercle of the superior molars and in the single external tubercle of the superior premolars."

The collections contain two species related to the Lemurs and family *Prosimiæ*, named *Cynodontomys latidens* and *Anaptomorphus homunculus*. The latter is remarkable for the small size of the canine teeth. The genus is nearest to *Tarsius* among the Lemurs. Contrary to the ordinary fact among the early Mammals, the brain and its hemispheres are not at all smaller than those of Tarsius or of the typical modern Lemurs.

3. *Report of the State Geologist of New Jersey*, Professor G. H. Cook, for the year 1881. 108 pp. 8vo, with a colored Geological Map of the State.—This report is devoted chiefly to the subject of New Jersey climate. With regard to the iron-ore districts, largely Archæan, the report gives the welcome information that the survey has had the construction of careful topographical and geological maps of the districts in progress for the two years past, and that the surveys now completed cover nearly three-fifths of the whole. The topography is based on the U. S. Coast Survey triangulation, and elevations will be given by carefully determined contour-lines for every twenty feet. By the aid of the maps, it is expected to make out completely the system in the distribution of the ore-beds so as to be able to point out where they are to be looked for and where not.

4. *Dioptase from Arizona*; by R. C. Hills. (Communicated.)—The rare mineral dioptase has been recently found at the Bon Ton group of mines, near the head of Chase Creek, about nine miles from Clifton, Arizona. It occurs in brilliant crystals lining cavities in what is called locally the "mahogany ore," a dark-brown compact mixture consisting principally of limonite and oxide of copper in varying proportions.

5. *Analysis of a variety of Siderite*; by Edo. Claassen. (Communicated).—This variety of siderite occurs on hematite in the Lake Superior Iron Region, Mich., either in single rhombohedral crystals, or more commonly in crystalline crusts. It is often also found associated with crystals of calcite, which then form on

the hematite a coating covered more or less by the crystals of siderite. The siderite has a light green color, which by exposure of the crystals to air and water turns brown and yellowish-brown. It gives the usual reactions for siderite, and also a slight manganese reaction. It contains

$FeCO_3$	$CaCO_3$	$MgCO_3$	$MnCO_3$	
66·240	28·362	5·391	trace	=99·993

or

FeO	CaO	MgO	MnO	CO_2
41·115	15·883	2·567	trace	40·428=99·993

According to the above analysis the ratio of $FeCO_3 : CaCO_3 : MgCO_3$ is $=9 : 4\frac{1}{2} : 1$.

Cleveland, O., Jan., 1882.

III. Botany and Zoology.

1. *The Names of Herbes.* By William Turner, A. D. 1548. *Edited* (*with an Introduction, an Index of English Names, and an Identification of the Plants enumerated by Turner*), by James Britten, F.L.S., of the British Museum, London; published for the English Dialect Society, Trübner & Co., 1881. The original full title is "The Names of herbes in Greke, Latin, Duch and Frenche wyth the commune names that Herbaries and Apotecaries vse. Gathered by William Turner." The dedication to the "Duke of Summerset" and preface addressed to him, is "from your graces house at Syon," and from Isleworth, almost under the shadow of Syon House, Mr. Britten issues his editorial preface. Full of instruction and quaint interest is this neat volume, of 134 pages, 8vo. A. G.

2. *A Synopsis of the North American Lichens*, part I, by Edward Tuckerman. Boston: Cassino, 1882. pp. 262, 8vo.— It is a great pleasure to receive this volume, which cryptogamic students have greatly needed and longed for. It is the first part of a work intended to describe all our North American Lichens; and we have here a very important portion of them, namely, the *Parmeliacei*, *Cladoniei* and *Cenogoniei*, arranged in the manner proposed by Prof. Tuckerman in his *Genera Lichenum*, published in 1872. In an introduction of seventeen pages the author briefly states his views with regard to the nature of Lichens, which he thinks ought, together with Algæ and Fungi, to be still considered as the three classes into which Thallophytes should be divided. With respect to the development of the lichen-thallus he follows in the main the views expressed by Minks in his work on the Microgonidium, and he adopts the account given by Bayerhoffer and Minks of the development of the spermogonium and apothecium. The remainder of the work is a systematic description of the species of the three families named above which occur in Arctic and temperate America. As usual,

Prof. Tuckerman has shown a wise conservatism with regard to the limitation of species, avoiding the excessive multiplications, founded on trivial or accidental distinctions, which characterize the writings of some modern lichenologists. Nor does he to much extent make use of chemical tests for the purpose of distinguishing species, as is done by Nylander and several European botanists, who have pushed this means of diagnosis to an extreme. The descriptions are clear and adequate, without being diffuse, and the botanist and student are now in position to determine North American Lichens with a degree of ease hitherto unknown: for the earlier writings of Prof. Tuckerman, as well as his Lichenes Exsiccati, have long been difficult or impossible to procure, and many of his recent writings are scattered in the proceedings of societies to which the botanical public do not generally have access. It is a rare good fortune for those interested in the study of our Lichens that the pioneer in this department of botany in America should also be the one to publish the first complete account of the species of the United States; for, in addition to his own great experience and protracted researches carried on in this country, Prof. Tuckerman in the very beginning of his botanical career was the personal friend and correspondent of Elias Fries, the most learned and acute lichenologist of his time. He has been able, so to speak, to transmit to us in this country the views of the fathers of the science with regard to North American species and their relations to European forms. In the case of marine algæ, Harvey unfortunately died before any one in this country began really to study that group of plants, and we are left in the dark as to many species about which Harvey alone could have given information. With the death of Curtis, too, students of Fungi lost the only person capable of pointing out with certainty in our fields and woods many of the larger fungi whose determination is now uncertain, but which would have been simple enough to one who had had personal instruction from Curtis.

As the greater part of the more striking Lichens belong to the *Parmeliacei* and the *Cladoniei*, the student will find most of the forms which he is likely to collect described in this first part of the Synopsis, and the determination of them should be by no means difficult, especially as Prof. Tuckerman is not given to excessive splitting up of species. The family of the *Collemiei*, however, must present difficulties even to experts. It seems to us on the whole advisable, in describing the gonidia (*gonimia*) of the genera of this family—entirely regardless of the fact whether one is a believer or disbeliever in the algo-fungal nature of lichens—to retain the names given by algologists to similar forms, as Nostoc-like, Glæocapsa-like, for such names accurately describe the forms present without necessarily committing one as to their nature. It is to be hoped that the learned author will soon give to the public the remainder of the Synopsis, including the very difficult *Lecidea* and *Verrucaria* groups, with which he alone of American botanists is able to cope. With the appearance of

Part II. we shall of course have the index of species and synonyms, of which, in using the present part, we feel the want. As no temporary index is given, we infer that the remainder of the work will soon follow. W. G. F.

3. *Botanische Mikrochemie;* by V. A. POULSEN, translated by CARL MÜLLER.—This little book is to be recommended to all persons in charge of laboratories where botanical work is carried on. It forms a small handy-volume to be kept on one's working table, and gives in a condensed form the reactions used to distinguish vegetable tissues under the microscope, with directions for preparing the various reagents, together with information as to the best way of mounting different botanical objects. The present German translation was made from the original Danish edition, with the sanction of the author, and although condensed in form, it can easily be read by any one having a slight acquaintance with German. We have not yet heard of its appearance in the American book market, but it can be ordered of the publisher, Theodor Fischer of Cassel, for a couple of marks. W. G. F.

4. *Nature and functions of the "Yellow Cells" of Radiolarians and Coelenterates.*—A paper under this title was read by Mr. Patrick Geddes before the Royal Society of Edinburgh in January last, and an abstract of it is given in Nature of January 26, from which we take the following notes. The "Yellow Cells" referred to, first so named by Huxley, occur abundantly in most Radiolarians. They have a well-defined nucleus and multiply rapidly by division. Haeckel made them probably secreting cells, or digestive glands in the simplest form. Cienkowski, in 1871, pronounced them parasitic algæ, and showed that they survived and multiplied after the death of the Radiolarians. Similar cells were later found in Velella, the oral region of some jelly-fishes, and in Anemones. The author in 1878 collected and analyzed the gas given out in direct sunlight by a Planarian, *Convoluta Schultzii*, and found it to be one-half oxygen, and further detected starch in the green cells. At Naples, in October, 1881, he confirmed the conclusions of Cienkowski as to the yellow cells of Radiolarians, and found starch invariably present. The same results were obtained with Velella, sea-anemones and jelly-fishes. On exposure to sunshine, a Velella gave out bubbles of gas which proved to be about one quarter oxygen, and similarly *Anthea cereus* gave gas which was 32 to 38 per cent oxygen; and among other sea-anemones those specimens in which the yellow cells existed gave a like result. A white Gorgonia contained the yellow cells and afforded the usual results, while a red variety of the same species failed of the cells and of the consequences. From the observations, Mr. Geddes concluded that the coloring matter, described as chlorophyl by Lankester, was derived from these endodermal algæ; also that the algæ aided the animal in its functions by supplying material for digestion when the alga dies; by removing carbonic acid and nitrogenous waste produced by the animal, thus performing an "intracellular renal function:" and by

supplying oxygen directly to the "surrounding animal protoplasm," "foreign chlorophyl thus performing the respiratory function of native hæmoglobin." Specimens of Anthea placed in the sunlight began at once to wave their arms as if pleasantly stimulated by the oxygen developed in the tissues. The fact of the absorption of the oxygen was apparently proved by experiment. A green alga (*Ulva*) gave, in the sunlight, gas containing 70 per cent of oxygen; a brown alga (*Haliseris*) 45 per cent; Diatoms, 42 per cent; while with animals containing the alga, as above shown, the amount of oxygen in the gas evolved is less than this and in all the trials except those with species of Ceriactis, much less. Mr. Geddes named the alga *Philozoon*, and distinguished four species, *P. radiolarum*, *P. siphonophorum*, *P. actinarum*, *P. medusarum*.

Mr. Geddes closes with the observation that the nearest analogue to the above described "partnership is to be found in the vegetable kingdom, where, as the researches of Schwendener, Bornet and Stahl have shown, we have certain algæ and fungi associating themselves into the colonies we are accustomed to call lichens, so that we may not unfairly call our agricultural Radiolarians and Anemones animal lichens."

5. *Ueber das Zusammenleben von Thieren und Algen.*—In connection with the preceding account of the paper of Mr. Geddes, attention should be called to a paper by K. Brandt, read before the "Gesellschaft Naturforschender Freunde" of Berlin, Nov. 15th, 1881. In the paper which bears the title above mentioned, Brandt gives the results of his investigations on the colored bodies in *Hydra*, *Spongilla*, a fresh-water *Planaria* and several Infusoria. The green bodies were obtained free by crushing the animals mentioned and were examined under a high power with the following result. Each body consisted of a colorless protoplasmic mass in which was imbedded a green bowl-shaped substance which proved on spectroscopic examination to be true chlorophyl. The protoplasm also showed a distinct nucleus. Brandt concludes that the green bodies are independent unicellular organisms to be classed with algæ and he describes the new genus *Zoochlorella*; one species, *Z. conductrix*, occurring in *Hydra* and *Z. parasitica* in *Spongilla*. He includes the yellow cells of the *Radiolaria*, *Hydrozoa*, and *Actinæ* in a new genus *Zooxanthella*. The green bodies obtained free by crushing *Hydra* and *Spongilla* did not die but continued to live for weeks on slides, and when exposed to the light starch was formed in them. That the species of *Zoochlorella* were not only morphologically but physiologically distinct was shown by this fact. The green bodies of *Spongilla* when absorbed by chlorophyl-free Infusoria were either digested or discharged unchanged, while the green bodies obtained from *Hydra* were absorbed and remained unchanged. Brandt concludes as follows: "So long as they are alive the *Zooxanthellæ* and *Zoochlorellæ* wholly support the animals in which they live. So long as the animals contain few or no green or yellow cells

they nourish themselves like true animals by the absorption of fixed organic material; as soon, however, as they contain a sufficient amount of Algæ they are nourished like true plants by the assimilation of inorganic material. Whenever in consequence of a lack of light the Algæ cannot perform their proper function they (the host-animals) must again nourish themselves like animals."

W. G. F.

Botanical Necrology.

Thomas Potts James.—With sorrow we have to announce the decease of one of our oldest botanists, which has taken place just when the fruits of long and laborious studies were nearly ready to be gathered. To Bryologists Mr. James' intimate acquaintance with mosses and his devotion to their investigation were not unknown. But the publication of the Manual of North American Mosses, by the two veterans, Lesquereux and James, for which we were waiting, would at once have resulted in wide appreciation of devoted services. Let us hope that the preparation of this long-desired volume is so far advanced that his equally venerable associate may soon complete and give it to the world. Nine years ago we rejoiced in having four devotees to Bryology, giving to this department unusual strength. In the spring of 1873, the unequalled leader and founder of the critical study of mosses in this country, Sullivant, was taken away, the keen-sighted Austin followed in the spring of 1880; and now, the present bereavement leaves Leo Lesquereux alone.

Mr. James died, at his residence in Cambridge, on the 22d of February, 1882, in the seventy-ninth year of his age. In his usual health he had attended the Ash Wednesday morning service and had resumed his daily task with the microscope, on rising from which in the afternoon, the rupture of a blood vessel of the brain brought on a paralysis of one side and a coma, to which he succumbed in a few hours.

Mr. James came of a notable stock of Penn colonists. His maternal ancestor, from whom his baptismal name was derived, was Thomas Potts, of Colebrook Dale, and his great great-grandfather, David James, immigrated from Radnorshire, in 1682, and settled at Radnor, Pennsylvania, near Philadelphia, where the subject of this notice was born, September 1, 1803. Circumstances prevented him obtaining a collegiate education at Princeton, for which he was preparing, and directed him to business affairs. He became a wholesale druggist, and carried on the business with success in Philadelphia for forty years, devoting the while his leisure to botany, for which he had a fondness from early youth. In December, 1851, he married Isabella Batchelder, of Cambridge, Mass., a lady of similar scientific tastes and of varied accomplishments, who with their four children survives; and in 1869 the family removed to Cambridge, where the remainder of his life was passed. In Philadelphia he was an active member of the leading scientific societies, especially of the old-

est one in the country, viz: the American Philosophical Society; of the Horticultural Society he was for twenty-five years the efficient Secretary; of the American Pomological Society he was one of the founders and for twenty-seven years the treasurer; of the American Pharmaceutical Society he was for many years an active associate; and after removing to Cambridge he was chosen a Fellow of the American Academy of Arts and Sciences, and a member of the Boston Society of Natural History. In Botany, after having become familiar with the phænogamous vegetation of the neighborhood of Philadelphia, he had the good sense to take up a specialty, and the perseverance to follow it up; and so he became a proficient and an authority in Bryology. His first published paper upon Mosses was contributed to the Proceedings of the Philadelphia Academy of Natural Sciences in the year 1854. Others appeared in the Transactions of the American Philosophical Society, and in the Proceedings of the American Academy of Arts and Sciences (the latter in connexion with Mr. Lesquereux); and to the Botany of Clarence King's Exploration on the Fortieth Parallel, he contributed the elaborate article on the Musci, in which several new species were characterized. After these successful essays, Mr. James was ready for more systematic work in his chosen field. The great desideratum was, and is, a Moss-flora of the United States. Mr. Sullivant, having completed his *Icones Muscorum*, was about to turn his attention to this greatly needed manual, in conjunction with his associate, Lesquereux, when he was taken from us. His surviving associate, deeply engaged in fossil botany, turned to Mr. James, who was able to give more time to this work; and our lamented friend, at a time of life when most men court repose, consented to joint authorship, and its onerous tasks, from a simple regard to the interests of his favorite science, and in view of the urgent needs of a rising school of botanists and amateurs, to whom mosses were becoming attractive. To this task Mr. James gave himself with single and untiring devotion. Owing to the state of his associate's eye-sight, the whole work of microscopical analysis has fallen upon Mr. James, has been most laboriously and conscientiously performed, and had been brought near to a conclusion when the pen and pencil dropped from his hand. Those who in future use the Manual of North American Mosses,—which we trust Mr. Lesquereux may finish and bring out at an early day,—and also the American Bryologists of the coming generation, building upon the foundations thus laid, will have good reason to honor the memory of these faithful pioneers who have opened and smoothed the way to a fascinating study. And the memory of Mr. James, the kindly, simple-hearted, devout, gentle man—admirable in every relation of life—is a prized possession of a large circle of acquaintances and friends.

Joseph Decaisne, the most eminent botanist in France, the director of the *Jardin des Plantes* ever since the death of Mirbel, the Professor of Culture in the Museum of Natural History at

Paris for more than forty years, died on the 8th of February, 1882, in the 75th year of his age. He was born at Brussels, March 11, "1809," according to Pritzel's Thesaurus; but this must be a misprint for 1807. He must have been a very young man when first attached to the Garden of Plants, it is said as a gardener. For it was there that he began the series of his published contributions to botanical science, in the year 1831; and he soon became *aide naturaliste* in that department of the Museum. He was elected into the Institute in 1847, taking the place in the Academy of Sciences vacated by the death of Dutrochet. In 1842, after the death of Guillemin, he was associated with Adolphe Brongniart in the editorship of the botanical part of the *Annales des Sciences Naturelles*, and has been sole editor since the death of Brongniart. In 1858 he began the publication of that great work, *Le Jardin Fruitier du Museum*, which was only a few years ago brought to a close. He had already produced (in 1837) his capital memoir on the anatomy and physiology of the Madder plant and the development of its coloring matter; also (in 1839), his investigation of the organization of the sugar-beet; his well-known paper upon the Mistletoe; his classical memoir on the *Lardizabalea*; his essay on the classification of *Algæ* and his restoration of the Corallines to the vegetable kingdom, not to speak of other papers and separate publications, all bearing the impress of his sincere and faithful workmanship. The same may be said, somewhat qualifiedly, of his elaboration of two orders for DeCandolle's Prodromus, the *Aselepiadeæ* and the *Plantagineæ*; but Decaisne worked slowly and with great painstaking, and was probably unable to give the requisite time for such monographs. He appears to full advantage only in separate and leisurely prosecuted investigations. Yet his work on the *Pomaceæ* might have been in truer perspective—according to the general judgment of botanists—if he had not so concentrated his attention upon this group as to view comparatively small differences under exaggerated proportions. But, withal there is much to be said for his decided opinion that the Apple, the Pear, and the Mountain Ash are of distinct genera. Decaisne was a capital draughtsman, and to his gifts in this regard we are much indebted for the *Traité Général de Botanique, descriptive et analytique* which he published in conjunction with LeMaout, in 1868, a veritable treasure to teacher and pupil. The older botanists will sadly feel the loss of Decaisne, and the *Jardin des Plantes* will be much changed to them, now that the last representative of the *régime* of Adrien de Jussieu and Brongniart disappears in the decease of this accomplished botanist and most amiable and excellent man.

To supply the omitted necrology of 1880 and 1881, the following memoranda are inserted:

Coe F. Austin, of Closter, New Jersey, died March 18, 1880, at the age of 49. He was a keen bryologist, and was preparing a manual of North American *Hepaticæ*.

Wm. Philip Schimper, leading bryologist as well as a foremost vegetable paleontologist, died March 20, 1880, at the age of 72. His rich and important herbarium of Mosses has been acquired by the Herbarium of the Royal Gardens at Kew.

Nils J. Andersson, the monographer of *Salix*, died at Stockholm, March 27, 1880, in the 60th year of his age. He had been in retirement for several years on account of infirm health.

General Wm. Munro, the learned agrostologist, to whom we looked for a *Species Graminum* (which was to be published in DeCandolle's Monographiæ), died at his residence near Taunton, England, January 29, 1880, at the age of 64; a sad loss.

Dominique Alexandre Godron, one of the authors of the *Flore de France*, died at Nancy, August 16, 1880, in the 74th year of his age.

S. B. Mead, one of our older local botanists, of much activity in former years, died at his home in Augusta, Illinois, November 11, 1880, at a good old age.

W. Lauder Lindsay, a learned lichenologist, and a writer upon the botany of New Zealand, died in November, 1880, at the age of 52.

Ernst Hampe, a veteran bryologist, died at Helmstedt, near Blankenburg in Hannover, where he had so long resided, November 23, 1880, at the age of 85. It has been said of him that when he began the study of Mosses, the 931 species enumerated by Bridel were all that were then known; in 1851, the number had risen to 2303, and they were estimated at 6000 at the time of his death. His berbarium has been acquired by the British Museum.

Alphonso Wood, the well-known author of some very popular botanical text-books and of one or two botanical papers, an enthusiastic devotee in botany, died at his residence in West Farms, New York, January 4, 1881, in the 71st year of his age. The Bulletin of the Torrey Club, of which Professor Wood was for many years a member, has a good biographical notice of him, vol. viii, p. 53–56.

Gottlieb Ludwig Rabenhorst, a mycologist of note, who has published very extensive and valuable *ersiccatæ* of cryptogamous plants, died near Meissen in Saxony, April 24, 1881, at the age of 74.

Matthias Jacob Schleiden, whose name and position in botany were very prominent forty years ago, when his text-book on scientific botany appeared, but who had so completely subsided from scientific pursuits that few were aware of his actual existence, died at Frankfort on the Maine, June 23, 1881, at the age of 77. The proposition that all vegetable tissues are formed of cells, which was fully announced by Mirbel, was made familiar by Schleiden. His countryman, early transferred to Belgium,

Theodore Schwann extended the proposition to animal tissues, and appears to have originated the idea that animal and vegetable cells, as the structural and physiological units of organic nature, were identical. Although like Schleiden, Schwann's name had

become one of the past, it appears that he actively fulfilled the functions of his professorship, first at Louvain (to which he was called in 1839, in his twenty-eighth year), and afterwards at Liége, quite down to the close of his life, early in the present year. His researches, published in 1839, upon which his scientific fame rests, appear to have been essentially his last, as well as his first contribution to science. It was a most noteworthy contribution, however, if it contained, as is said, the announcement that animal tissues originate in cells, that Bacteria are the cause of putrefaction, and that alcoholic and analogous fermentations are produced by plants. A. G.

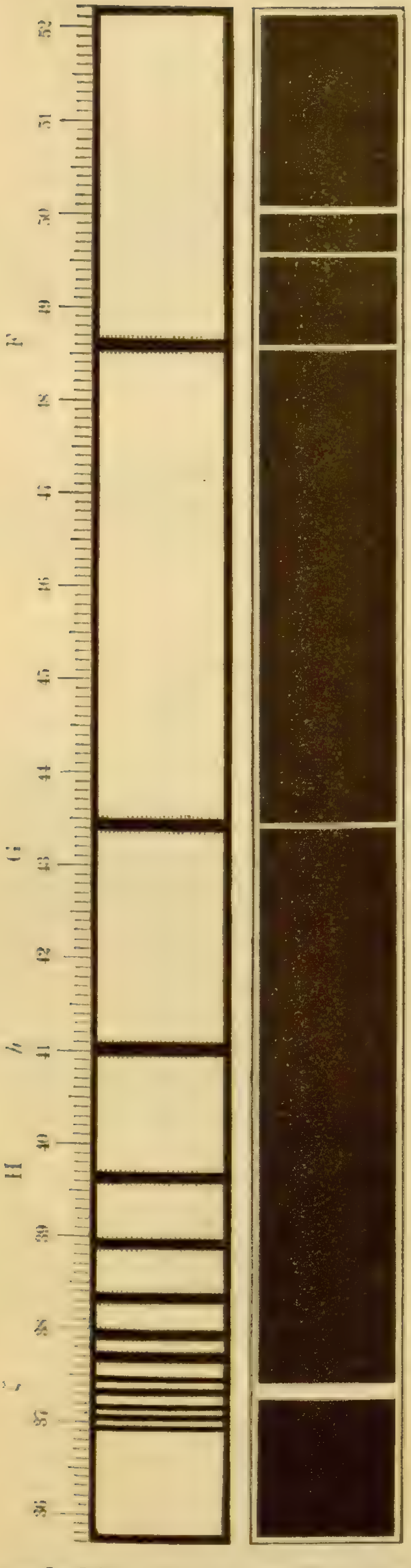
6. *The Census Report on the History and Present Condition of the Fishing Industries*; prepared under the direction of Professor S. F. Baird, U. S. Commissioner of Fish and Fisheries, by C. Brown Goode, Assist. Director U. S. Nat. Mus. *The Seal-Islands of Alaska*; by Henry W. Elliott. 176 pp. 4to, with 29 plates and other illustrations.—This volume treats of the Fur Seal Islands (the Pribylov), and the seals, with great fulness, from all practical and scientific points of view. Its plates illustrate the seal in various attitudes and conditions, singly, and in indefinite multitudes along the shores, and also the walrus, sea-lion, and birds of the region; and contains views of the people, and their houses, the coast scenery, and maps of the sealing region. The number of seal skins taken to market from the Pribylov Islands (St. George and St. Paul), in 1880, was 100,000. These islands lie in the Bering Sea (not Behring, remarks the author), between latitudes 56° and 57° and the meridians 168° and 170°, about 200 miles west of Cape Newenham. They are volcanic in origin, but have no active fires.

IV. Astronomy.

1. *Micrometrical Measurements of 455 Double Stars*, 1879–80: Publications of the Cincinnati Observatory, No. 6, University of Cincinnati. Cincinnati, 1882. Large 8vo, pp. 69.—The sixth contribution to the Astronomical literature of double stars is alike creditable to the University of Cincinnati, Professor Stone personally, and the printer. Perhaps it would be not an easy matter to find a better illustration of the wisdom in confining the staff of a moderately equipped observatory to such observations as do not imply expensive or tedious reduction, than is given in the consecutive publications of the observatory since it resumed its activity under Professor Stone. The observations seem to be made with continuous care, according to a fixed system, and with due regard to personal and systematic errors. The results are given in excellent shape for present reference or for the examination of them at a future time for errors too subtle to be now suspected. L. W.

2. *Names of small Planets.*—The following names have been given to recently discovered planets:

212 Medea,	218 Bianca,
216 Cleopatra,	219 Thusnelda.



3. *Photograph of the Spectrum of the Great Nebula in Orion*; by WILLIAM HUGGINS. (Communicated by the Author.)—On Tuesday night, 7th March, I obtained a photograph of the spectrum of the nebula in Orion, with an exposure of 45 minutes. The spectroscope and special arrangements attached to the Cassegrain telescope of 18 inches aperture were the same as were employed in obtaining the photographic spectra of the stars. My former researches showed that in the *visible* spectrum of the gaseous nebulæ four bright lines can be seen. The strongest, coincident with the less refrangible component of the brightest double line of the nitrogen spectrum, has a wave-length 5005. The next line is at λ 4957. The other two lines coincide with Hβ (F) and Hγ of the hydrogen spectrum.

On the photographic plate these four lines can be seen, but in addition there is a strong line in the ultra-violet at the position of λ 3730, or very nearly so, as the wide slit does not permit of quite the same high degree of accuracy of measurement as was possible in the case of the spectra of the stars.

It is very probable that this new line coincides with the line ζ in the typical spectrum, as shown by my photographs, of the brightest white stars. For the convenience of comparison I have placed this typical spectrum by the side of the spectrum of the nebula. I could not be certain if any *faint* lines are present between Hγ and the new line at λ 3730, and also beyond this line. I hope by longer exposures and more sensitive plates to obtain information on these points.

There was a faint continuous spectrum on the plate, which was probably due to stellar light. The bright stars of the Tra-

pezium were placed close outside the slit, so that the light of the brightest part of the spectrum might pass in to form the spectrum.

4. *Linear Associative Algebra*; by BENJAMIN PEIRCE, with notes and addenda by C. S. PEIRCE, son of the author.—This work, which the distinguished author always regarded as his best contribution to science, was published in his lifetime only by a limited edition in lithograph for personal distribution. Notwithstanding its value it has been therefore difficult for mathematical students to have access to it. Its reproduction in the American Journal of Mathematics is a real boon to science. H. A. N.

V. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Voyage of the Vega round Asia and Europe, with a Historical review of previous journeys along the North Coast of the Old World*; by A. E. NORDENSKIÖLD. Translated by ALEXANDER LESLIE. 756 pp. 8vo, with numerous maps and illustrations and fine steel portraits. London and New York, 1882. (Macmillan & Co., N. Y.)—This large volume is one of great interest to all readers. It is a contribution to the subjects of ancient as well as modern geography, ancient explorations of the northern regions as well as the most recent, old maps and new, old style of ship building in the north and the construction of the Vega, the deep-sea life to some extent and that of the shores and the land, with reproductions of quaint old pictures of polar bears, the walrus and other Arctic species and finished sketches illustrating these species, and also to ethnological, linguistic and other departments, besides giving an account of the incidents, sights and discoveries of the voyage. The portraits include an excellent one of Nordenskiöld.

2. *Guides for Science Teaching*, issued under the auspices of the Boston Society of Natural History. Ginn, Heath & Co., Boston, Publishers. 1879 to 1881.—These small primers, of 24 to 64 pages each, are by authors well versed in the several subjects treated, and will be found of much value to teachers and learners. The titles of the seven before us are: About Pebbles, by ALPHEUS HYATT; Concerning a few Common Plants, by G. L. GOODALE; Commercial and other Sponges, illustrated by several plates, by A. HYATT; A First Lesson in Natural History, by Mrs. AGASSIZ; Common Hydroids, Corals and Echinoderms, by A. HYATT, illustrated by several plates; The Oyster, Clam and other Common Mollusks, by A. HYATT, well illustrated by plates; Common Minerals and Rocks, by WM. O. CROSBY.

3. *Potassium permanganate.*—Dr. J. B. DELACERDA, after careful experimenting, has reached the conclusion that this salt is an antidote to the poison of the Cobra; and that it acts through the disengagement of oxygen as a consequence of its decomposition in the system.

4. *Index to the Reports of the Chief of Engineers and the officers of the Corps of Engineers, United States Army, upon*

Works and Surveys for River and Harbor Improvement, 1866–1879.—Compiled under the direction of Maj. HENRY M. ROBERT, Corps of Engineers, by L. Y. SCHERMERHORN, C.E., S. O. L. POTTER, A.M., M.D., and others. 624 pp. 8vo. Washington, 1881.—The reports of the Engineer Department embrace so wide a range of facts and of careful investigations as regards all scientific and practical questions connected with rivers, lakes, harbors, canals, bridges, improvements by levees, dikes and other means, and the materials and methods of construction, and contain so important contributions to the sciences of hydraulics, dynamical geology and geography, made over the breadth of the American Continent, that this Index volume is one of great value and very general interest. Besides this, they are full of local details as to surveys and improvements in all parts of the country.

5. *Earthquake of March* 4, 1881, *in Ischia.*—The first number of "Humboldt," the new German scientific monthly published by Enke at Stuttgart, opens with a paper by Dr. A. v. Lasaulx, "Das Erdbeben von Casamicciola auf Ischia." The author argues that as the shock was only slightly felt on the island of Procida and not at all on the opposite mainland, the origin must have been at a less depth than the sea-bottom of the intervening strait. And since the district most violently affected is bounded by an oval whose long diameter is east-west and therefore not radial to the volcanic center of the island, which lies to the south, the cause is not to be sought in the volcanic activity of this Mount Epomeo. He attributes the earthquake to subsidence of deep-lying strata, due to hollows caused by removal of material in solution by the numerous hot springs. C. G. R.

6. *The Swiss Seismological Commission.*—We gather from Comptes Rendus (Dec. 26, 1881) and from Nature (Jan. 12, 1882) some particulars in regard to the work of this Commission since it began operations in the fall of 1879. Its members have published a number of papers, which have been recently presented to the French Academy by M. J. L. Soret. Among these are: 1. Note on Earthquakes and their scientific study, by M. Heim; 2. Note on the Seismometric Observations in Switzerland, by M. Forster; 3. Report on the Earthquake of Dec. 30, 1879, by M. Forel; 4. Report on the Earthquakes from November, 1879, to December, 1880, by M. Heim; 5. Note on the same period, by M. Forel; 6. Note on the Earthquakes of November, 1881, by M. Forster. M. Heim writes in German, the others in French, and the first paper is translated into French by M. Forel. In presenting these papers to the Academy, M. Soret cited a number of interesting facts from which we take only two. Some shocks, as those of July 4, 1880, and March 3, 1881, occurred almost simultaneously throughout Switzerland and Northern Italy. These and others appeared also to have spared a considerable part of upper Savoy; being felt, for example, with considerable intensity on the north bank of Lake Geneva, and but slightly on the southern shore, although this was nearer the probable source

of the disturbance; as if this district were, from the seismic point of view, under conditions different from those which affect adjacent cantons. The month of November, 1881, was also marked by special seismic phenomena. According to a note by M. Forel in "La Suisse Liberale" of Dec. 14, 1881, twenty-nine distinct shocks of earthquake had occurred within the month, and of its thirty days there were only thirteen on which an earthquake did not occur in some part of Switzerland. They were traceable to three principal centers; the first, at the commencement of the month, in the Pays d'Enhaut and the Vaudoise Alps; the second in Eastern Switzerland; the third, at the end of the month, in the lower Valais, from Martigny to Lake Geneva.

C. G. R.

7. *Glacier scratches in the Catskills.*—Dr. Julien, in the Transactions of the New York Academy of Sciences, vol. i, no. 2, states that he has found no *glacial scratches* near the Clove above 2,900 feet, the highest observed occurring on the "High Ledge," Parker Mountain, at 2,874 feet, and on the southeast slope of Round Top, at 2,871 feet; the direction of the former S. 18° W., magnetic; of the latter S. 35° E. He remarks that the highest scratches observed in the Catskills occur on Overlook Mountain, at an elevation of about 3,100 feet, showing that the ice surface was at least 3,200 over this part of the Catskill region. He concludes that there were two movements over the region—the movement of the Continental glacier southeastward, and that of the Hudson River valley, southward.

8. *Geological Survey of Great Britain.*—Professor Archibald Geikie has been appoined Director-General of the Geological Surveys of Great Britain and Ireland and Director of the Museum of Practical Geology in London.

The Constants of Nature. Part V: A recapitulation of the Atomic Weights, by F. W. Clarke, Prof. Chem. and Phys. Univ. Cincinnati. Smithsonian Miscellaneous Contributions, No. 441. 280 pp. 8vo. Washington, 1882.

Fifty Years of Science, being the Address delivered at York to the British Association, August, 1831, by Sir John Lubbock, President of the Association. 90 pp. 8vo. London, 1882. (MacMillan & Co.)—The extracts from this address in a former volume of this Journal are enough to create a desire for this volume which gives it entire.

Obituary.

Sir Charles Wyville Thomson died on the 12th of March, at the age of fifty-two. He was born at Bonsyde, Linlithgowshire, on the 5th of March, 1830. His exploring expeditions in the Lightning, Porcupine and Challenger, in which the "depths of the sea" in the Atlantic and around the world were investigated with remarkable success and multitudes of new discoveries, have made his name familiar to the people of all civilized lands. The publications of his last expedition are still in progress. After graduating at the University of Edinburgh, he was appointed, in 1850, Lecturer on Botany in King's College, Aberdeen, and, in 1870, Regius Professor of Natural History in the University of Edinburgh. His so early departure is greatly to be deplored.

THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

Art. XXXV.—*On Photographs of the Spectrum of the Nebula in Orion;* by Henry Draper, M.D.*

For about eighteen months I have been giving attention to the Nebula in Orion with two objects in view, first to ascertain whether any changes are taking place in that body by making a series of photographs to be compared in the future with a similar series; and second, to photograph the spectrum of the Nebula in various parts so as to see whether any new lines could be found, and also whether the composition is uniform throughout.

As to the first of these objects I have recently succeeded in taking a very fine and extensive photograph of the Nebula containing most of the delicate outlying parts which were not in my earlier photographs. This is in the hands of the photo-lithographer now and will shortly be published. The experiments have been very difficult because an exposure of more than two hours in the telescope has been necessary, and an exceedingly minute motion of the stars relative to the sensitive plate will become apparent on account of the high magnifying power (180), employed.

In carrying out the second object two contrivances have been used; first, a direct vision prism in the cone of rays from the objective before they had reached a focus, and second the two-prism spectroscope with which I have taken photographs of stellar spectra for some years past.

* Read before the National Academy of Sciences, April, 1882, at Washington.

During the month of March I have made two good photographs with each of these arrangements. Those with the direct vision prism, without a slit, have of course demanded that the image should be kept stationary on the sensitive plate throughout the exposure, viz., two hours, and they are as difficult to get as good photographs of the nebula itself. On the contrary, those obtained with the slit spectroscope do not require the same steadfast attention.

The results derived from these photographs are interesting partly from what they show and partly from what they promise in the future. A number of photographs, under various conditions, will be needed for the full elucidation of the subject.

The most striking feature is perhaps the discovery of two condensed portions of the nebula just preceding the trapezium, which give a continuous spectrum. At those places there is either gas under great pressure or liquid or solid. I have not been able to detect any stars of sufficient magnitude in these portions to produce this effect either in my photographs of the nebula or in any of the well known drawings of this object. It seems to me also that the photographs show evidence of continuous spectrum in other parts of the nebula. In these respects the conclusions arrived at by Lord Rosse in his memoir (Phil. Trans. Royal Society, June 20, 1867, page 70), are to a certain extent borne out.

The hydrogen line near G, wave-length 4340, is strong and sharply defined; that at *h*, wave-length 4101, is more delicate, and there are faint traces of other lines in the violet. Among these lines there is one point of difference, especially well shown in a photograph where the slit was placed in a north and south direction across the trapezium; the Hγ line, λ 4340, is of the same length as the slit and where it intersects the spectrum of the trapezium stars a duplication of effect is visible. If this is not due to flickering motion in the atmosphere it would indicate that hydrogen gas was present even between the eye and the trapezium. I think the same is true of the Hδ line, λ 4101. But in the case of two other faint lines in this vicinity I think the lines are not of the length of the slit, one being quite short and the other discontinuous. If this observation should be confirmed by future photographs of greater strength it might point to a non-homogeneous constitution of the nebula though differences of intrinsic brightness would require to be eliminated.

The April number of the American Journal of Science contains an account of a photograph of the spectrum of this nebula taken by Dr. Huggins. I have not found the line at λ 3730, of which he speaks, though I have other lines which he does not appear to have photographed. This may be due

to the fact that he had placed his slit on a different region of the nebula or to his employment of a reflector and Iceland spar prism, or to the use of a different sensitive preparation. Nevertheless, my reference spectrum extends beyond the region in question.

As illustrating the delicacy of working required in this research it may be mentioned that in one of these photographs the spectrum of a star of the tenth magnitude is easily discerned. It is only a short time since it was considered a feat to get the image of a ninth magnitude star, and now the light of a star of one magnitude less may be photographed even when dispersed into a spectrum.

271 Madison avenue, New York.

ART. XXXVI.—*Mean Annual Rain-fall for different Countries of the Globe;* by Dr. ALEXANDER WOEIKOF of St. Petersburg, Russia.

PROFESSOR E. LOOMIS having published in this Journal a paper on the rain-fall of the world (Contributions to Meteorology, paper xvi), inviting meteorologists to give supplementary information on this subject, I readily accept this invitation, having myself given much attention to the subject. I must remark first on the exceeding inaccuracy of the geographical delineations used on the map, (mountains, lakes, rivers, etc.,) an inaccuracy which, however, certainly did not mislead Professor Loomis, when he was drawing his lines of equal rain-fall for countries where observations are wanting, and where the geographical configuration and notices of travelers are the only objects which give a basis to the hypotheses. I will give only examples in relation to Africa and Asia. On the first continent not only are none of the equatorial lakes given, but even no mountains in Abyssinia, while we find "Donga Mountains," between 4°–6° N. and 20°–30° E., which have no existence. In Asia the Stanovoi watershed between the systems of the Lena and Amur is given as if it was a high mountain chain; the same is to be said of the slope of the Mongolian plateau north of Pekin, while between 25°–40° N. and 96°–110° E., no mountains are shown, while this region comprises West China, Kukunor and Eastern Thibet, and has some of the highest chains of Asia.

I come now to Professor Loomis's work in Europe. The shades are mostly right, except—

1. Sicily, which has, in its greatest part less than 25″.
2. Portugal, where the author cites the old and erroneous

figures for Coimbra, while Professor Hann has some years ago proved, by the results of the new observations, that it has a rain-fall not much above that of Lisbon.

3. Scandinavia, where the fall above 50″ is restricted to a few exceptional places, near high mountains of West Norway, like Bergen and Floroë. Even Christiansund has much less. Eastern Norway and the interior valleys (Christiania, Dovre) have less than 25″.

In what concerns European Russia, the shading is perfectly right, as I have found by a new and more extensive collection of data. The frontier of the fall of more and less than 10″ is also in the main right, except in the vicinity of Orenburg, where it should be drawn somewhat more to the south.

In Asia, north of the Tropics, there is more to change. Thus the zone of less than 10″ in the Arabo-Caspian steppes and vicinity is too large in Professor Loomis's map. It does not stretch so far to the north and northeast, and certainly does not reach to the foot of the Altai, where the rains of summer and the snows of winter are rather abundant. On the east coast of the Caspian, Krasnovodsk (40° N.) has also more than 10″.

There is a great rain-fall on the south shore of the Caspian, as well as on the south part of the western shore; on the latter Professor Loomis has the station of Lenkoran 51·7″.

The country about Lake Balkash and the upper Irtysh is very dry, it being really a continuation of the Arabo-Caspian steppes, there being a broad gap in the mountains. The dry region in Mongolia and Eastern Turkestan must be extended westward so as to include Yarkand and Kashgar; on the north, on the contrary, it does not extend as far as shown by Professor Loomis, Kiakta and Ourga having more than 10″. The good pasture and forest in this region prove that the two latter stations are not exceptional. I should rather include most of the basin of the Yang-tze and eastern Indo-China in the region having more than 50″, though I have no observations to prove my case. But the known humidity of the region, the luxurious vegetation, the immense floods of the rivers* corroborate my opinion. Eastern Java seems to have less than 75″, as is seen by the 5½ years of Surabaya and 2 years, 1879–80. It would be safe to give 50″–75″ to the islands east of Java so far as Sumbawa, and a shade less to Flores and Timor, while Banca, Billiton and the Moluccas and Southern Philippines have probably over 75″.

As to British India, Professor Loomis has made a good use of the numerous observations there.

* See E. L. Oxenham, Inundations of the Yang-tze-Kiang, in Jour. Roy. Geogr. Soc., 1875, p. 170.

In Western Asia the region of 10″–25″ is probably in closer proximity to mountains than shown in Professor Loomis's map, extending far to Shiras along the mountains of southern Persia, and not so far to the south in southeast Syria and Mesopotamia. In Arabia a closer approximation of the rainy regions to the mountains is also what must be the case.

As to Africa, Professor Loomis has made good use of the observations and general information of travelers, with the exception of Abyssinia, which has certainly more rain than indicated by him. That North America north of the Tropic is accurately represented by Professor Loomis is easily understood. I would only ask, is it not probable that Northern Canada from about 50° N. lat. is less rainy than supposed by Professor Loomis, so that the more abundant rain of the coast of Labrador would be caused by its position relatively to the sea and mountains?

As to Central America, the dark shade given to Yucatan is rather doubtful. The short period of rain, the absence of mountains and the rather scanty vegetation, at least of Northern and Western Yucatan would rather point to less rain, though the porous nature of the limestone absorbs much water. So far as I could see and learn, Tehuantepec and Northern Yucatan must have about the same quantity of rain.

As to the Pacific coast, from about Tonala to Panama it must have above 50″. A few observations made in Nicaragua give a large amount of rain, and Nicaragua is certainly less rainy than the coast of Soconusco about Tapachula and Guatemala. The city of Guatemala has a little less than 50″, but the plateau on which it is situated is generally dryer.

Tropical South America, at least its interior, is the part of Professor Loomis's map which is least accurate. I am at a loss to know on what account the Amazonian country is supposed to have less rain than the dry "llanos" of Venezuela to the north of it. I consider it probable, that from the north coast to 15° S. lat., the only parts east of the Andes, where there is less than 50″ rain, are the llanos of Venezuela and perhaps part of the Magdalena basin. On or near the Amazon, we have Para, Manaos and Iquitos, which give more than 50″. The latter is especially interesting. The distance from the Andes is more than 200 miles, from the Atlantic more than 1000, the country perfectly level, and yet there are 111·8″ rain. Generally it is mentioned by travelers, that to the south of the Amazon the rains are less heavy, and yet San Antonio on the Madeira has 91·3″.

As to the west coast, the region of more than 75″ extends certainly to the equator, the provinces of Esmeraldas and Choco being described as exceedingly rainy. Farther to the south I would object to giving to Chiloe and the adjacent coast

less rain than to Concepcion and Valdivia. Professor Loomis probably made use of the observations at Ancud, Chiloe, and seeing that this place had less rain than Valdivia and Puerto Montt, took it as generally admissible for the latitudes above 41° S. on the west coast. But Ancud is protected by a rocky promontory on the west, that is, the wind and rain side, while the other two stations are open to the west.

In the LaPlata States the interior is very dry, only the eastern slopes of the mountains and their vicinity have more rain. Now all the interior stations from which we have rain observations, are so situated, and all except Mendoza give much more rain than would be the average of more evenly distributed stations. We know that westward from the stations of Cordoba, Tucuman, Salta are the States of Catamarca, Jujuy, San Luis, which are so dry that even good pasturage is scarce. It would thus be safe to extend the region with less than 10″ much to the eastward, and that of 10″–25″ also.

As to Australia, the region of 25″–50″ in the north of the Continent probably extends along the coast somewhat to the southwest from the position given it by Professor Loomis. As to that of less than 10″ there is no reason why we should admit that it is so very restricted in the interior as in Professor Loomis' map. We have no observations from an extensive district, but what we know of the dryness of the interior allows us to make this very probable supposition.

On the whole, Professor Loomis's work is certainly a good one, but on account of what I have mentioned above, a revised edition of the map is yet desirable.

I would besides draw attention to some perplexing and erroneous designations of the countries and regions in which are situated some of the stations mentioned by Professor Loomis. I give here some of them, with the corresponding numbers of Professor Loomis's table.

254 *Ragusa*, European Turkey. Is situated in the Austrian province of Dalmatia.

363 *Ajansk*, Russia. As other places in Siberia are cited as such, it would be better to mention Ajan, the exact name, as being in Eastern Siberia. The same applies to 524 *Nertschinsk*, 522 *Irkuzk;* 646 *Kjachta*, 510 *Enisseisk;* while 512 *Tobolsk*, 516 *Tomsk*, 517 *Ischim*, 519 *Omsk:* 520 *Isalair* (*Salair*), 643 *Barnaoul*, 644 *Akmolinsk* are situated in Western Siberia.

521 *Nikolaiewsk*, 525 *Blagowestcheuck*, 526 *Chabarowka*, 528 *Vladicostok* are placed by Professor Loomis in China, while they are in Eastern Siberia (in the Amur and Littoral provinces).

The appellation Tartary applied to 529 *Tashkent*, and 647 *Irgis* is wanting in precision. If it is meant for the Kirghiz

steppes, Russian Central Asia and the Khanates of Khiva and Bokhara, then the following stations should also be included in it: 649 *Raïmsk*, 650 *Fort N.* 1, 652 *Novo Petrovsk*, 653 *Nakust Mekuss*, 654 *Petro-Alexandrovsk*.

I give below some data about rain-fall, especially in relation to countries which, in my opinion, are not correctly represented in Professor Loomis's map.

Names of Places.		Lat.*	Long.*	Ht. met'rs	No. of Years	Rain. Inch's.	Authority.
Manaos, Brazil		−3° 8′	−60°	37	1	55·2†	Zeitschr. v. 8. p. 267
Iquitos, Peru		−3 44	−73° 8′	95	1	111·8	Zeitschr. v. 8. p. 267
S. Antonio, Madeira, Brazil		−9 5	−64	....	1	91·3	Zeitschr., v. 15. p. 492
Pernambuco, Brazil		−8 4	−34 52	3	4	108·4	Zeitschr., v. 14, p. 216
Surabaya,	Eastern Java.	−7 13	112 48	....	5½	71·7	Zeitschr., v. 8, p. 56
Passœrœan,	Eastern Java.	−7 38	112 56	4	2	63·1	Bergsma Z. 1879 and 1880
Probolingo,	Eastern Java.	−7 44	113 13	10	2	57·33	Bergsma Z. 1879 and 1880
Besœki,	Eastern Java.	−7 43	113 41	2	2	57·76	Bergsma Z. 1879 and 1880
Sitœbondo,	Eastern Java.	−7 41	114 2	80	2	57·05	Bergsma Z. 1879 and 1880
Banjœwang,	Eastern Java.	−8 13	114 23	5	2	68·83	Bergsma Z. 1879 and 1880
Amboina,	Moluccas	−3 42	128 10	....	2	190·50	Bergsma Z. 1879 and 1880
Banda,	Moluccas	−4 32	129 53	....	2	135·77	Bergsma Z. 1879 and 1880
Urga, N. Mongolia		47 55	103 50	....	6	10·13	Met. Annalen
Kiakhta,	S. E. Siberia	50 21	106 25	....	4	10·09	Met. Annalen
Irkutsk,	S. E. Siberia	52 17	104 22	....	6	17·38	Met. Annalen
Barnaul,	S. W. Siberia	53 20	83 57	....	41	9·50	Met. Annalen
Akmolinsk,	S. W. Siberia	51 12	77 23	....	6½	9·53	Met. Annalen
Semipolatinsk,	S. W. Siberia	50 24	80 13	....	5	8·39	Met. Annalen
Salaïr (Altaï),	S. W. Siberia	54 15	85 47	346	4	13·0	Met. Annalen
Vladikavkas, N. Caucasus		43 0	45 3	....	8	34·04	Met. Annalen
Stavropol		45 5	41 53	....	13	27·74	Met. Annalen
Poti,	E. co't of Bl'k Sea, Trans Caucasia	42 10	41 40	....	10	65·92	Met. Annalen
Suchum-Kale,	E. co't of Bl'k Sea, Trans Caucasia	42 58	40 53	....	3½	50·51	Met. Annalen
Dachovsky-Possad	E. co't of Bl'k Sea, Trans Caucasia	43 34	39 42	....	9	80·81	Met. Annalen
Novorossissa,	E. co't of Bl'k Sea, Trans Caucasia	44 43	37 46	....	4	30·02	Met. Annalen
Sevastopol, Crimea		44 36	33 32	....	14	15·37	Met. Annalen
Christiania,	S. Norway	59 55	10 43	...	7	21·18	Zeitschr. v. 4. p. 508
Sandösund,	S. Norway	59 5	10 28	....	7	23·01	Zeitschr. v. 4. p. 508
Christiansund,	W. co't Norway	63 7	7 45	....	7	33·18	Zeitschr. v. 4. p. 508
Aalesund,	W. co't Norway	62 29	6 9	....	7	45·53	Zeitschr. v. 4. p. 508
Catania (E.),	Sicily	37 24	15 3	....	12	18·05	Fischer. Klima der Mittelmeerländer Gotha, 1879
Syracuse (E.),	Sicily	37 4	15 17	....	10	18·27	Fischer. Klima der Mittelmeerländer Gotha, 1879
Palermo (N.),	Sicily	38 7	13 19	....	61	23·27	Fischer. Klima der Mittelmeerländer Gotha, 1879
Sciacca (S. W.),	Sicily	37 30	13 5	....	10	22·26	Fischer. Klima der Mittelmeerländer Gotha, 1879
Oporto, Portugal		41 9	−8 36	....	10	56·34	Fischer. Klima der Mittelmeerländer Gotha, 1879
Coïmbra, Portugal		40 13	−8 25	....	6	34·0	Fischer. Klima der Mittelmeerländer Gotha, 1879
Lissabon, Portugal		38 43	−9 10	....	20	28·80	Fischer. Klima der Mittelmeerländer Gotha, 1879

* The sign − stands for lat. S. and long. W.

† The observations were continued only ten months and gave 49·9″, the two remaining, July and August are interpolated.

Art. XXXVII.—*Notes on Physiological Optics*; No. IV; by W. LeConte Stevens.

1. On Voluntary Control of Focal Accommodation.

In my last paper the visual effect of associated muscular action of the two eyes was discussed, the investigation having led to the discovery of a new mode of stereoscopy. Experiments have also been made on the effect of muscular action in a single eye.

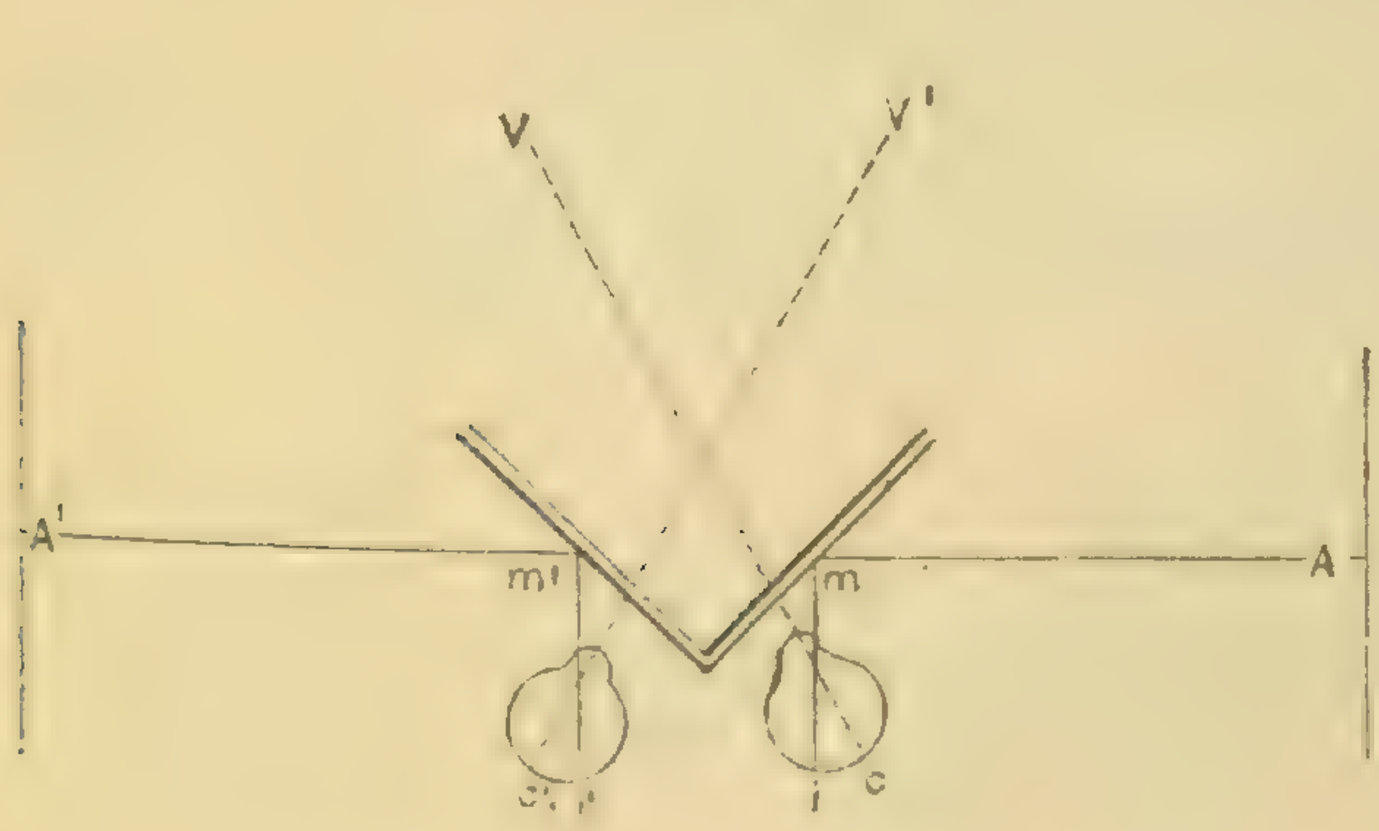
If the axial adjustment and visual angle be kept as nearly as possible unchanged while the gaze is directed upon a luminous surface, such as the globe of a gas lamp, it is very easy to throw the crystalline lens of each eye out of focus, accommodating for a nearer point, so that the object appears blurred in consequence of the production of diffusion circles on the retinas. I find it possible in this way to exercise extreme contraction of the ciliary muscle at will. It is impossible to avoid slight associated contraction of the internal rectus muscles, but this may be controlled to such an extent that the only effect noticeable is unsteadiness of one eye, while the other is directed to some previously clearly defined object. The effect is first an encroachment of diffusion circles upon the surrounding retinal area as well as upon the image itself, producing dimness of vision and hence apparent enlargement of the object which is necessarily ill-defined. But as the ciliary contraction increases, the object apparently diminishes in size to a marked extent, sometimes almost to half its previous area, while the halo due to diffusion circles does not widen, but on the contrary grows narrower. This is due to the contraction of the pupil, the effect being that of using a new stop in front of the lens, as it thickens and acquires more "depth of focus," while its theoretic focal length is less. The pupillary contraction can be noted by an assistant and approximate measures be made of the change in diameter of the opening. This pupillary change very quickly follows the contraction of the ciliary muscle. The area of my pupil has thus been repeatedly diminished, within two seconds of time, from 12 sq. mm. to 1·2 sq. mm. The estimated distance of the object is very uncertain. It may be judged nearer because of the dimness due to imperfect focalization. The only perfectly clear perception therefore, is that of marked decrease in area, far greater than can be referred to mere encoachment of diffusion circles. The distance between retina and lens remains sensibly constant, hence the perception is an illusion due mainly to abnormal muscular conditions.

Since in normal vision the contractions of the ciliary and internal rectus muscles are associated, the considerations just expressed show why so acute an observer as Wheatstone should have noticed the apparent decrease in size of the binocular image when strong convergence of visual lines was induced by pulling forward the arms of his reflecting stereoscope,* but failed to note the corresponding variation in apparent distance, though he observes that the image seems changed in position, but does not say whether the change is that of increase or decrease in distance.

2. Effect of Muscular Effort on Retinal Sensitiveness.

The estimation of size and distance, when there is strong, muscular effort, depends in some measure upon the part of the retina on which the image is formed, variations being more noticeable when the central part is impressed. In a former paper† I briefly noted the following experiment with Wheatstone's stereoscope. Let A and A′ (fig. 1), be a pair of conjugate pictures adjusted so that the reflected rays, $m\,i$ and $m'\,i'$, are sensibly parallel. If the visual lines of the eyes receiving these rays coincide with them, the image appears in front, combined in full relief, with apparent diameter and distance slightly magnified, the contraction of the internal rectus muscles being less than normal. Let the visual lines now be forcibly crossed. The retinal images, i and i', are no longer upon corresponding

1.



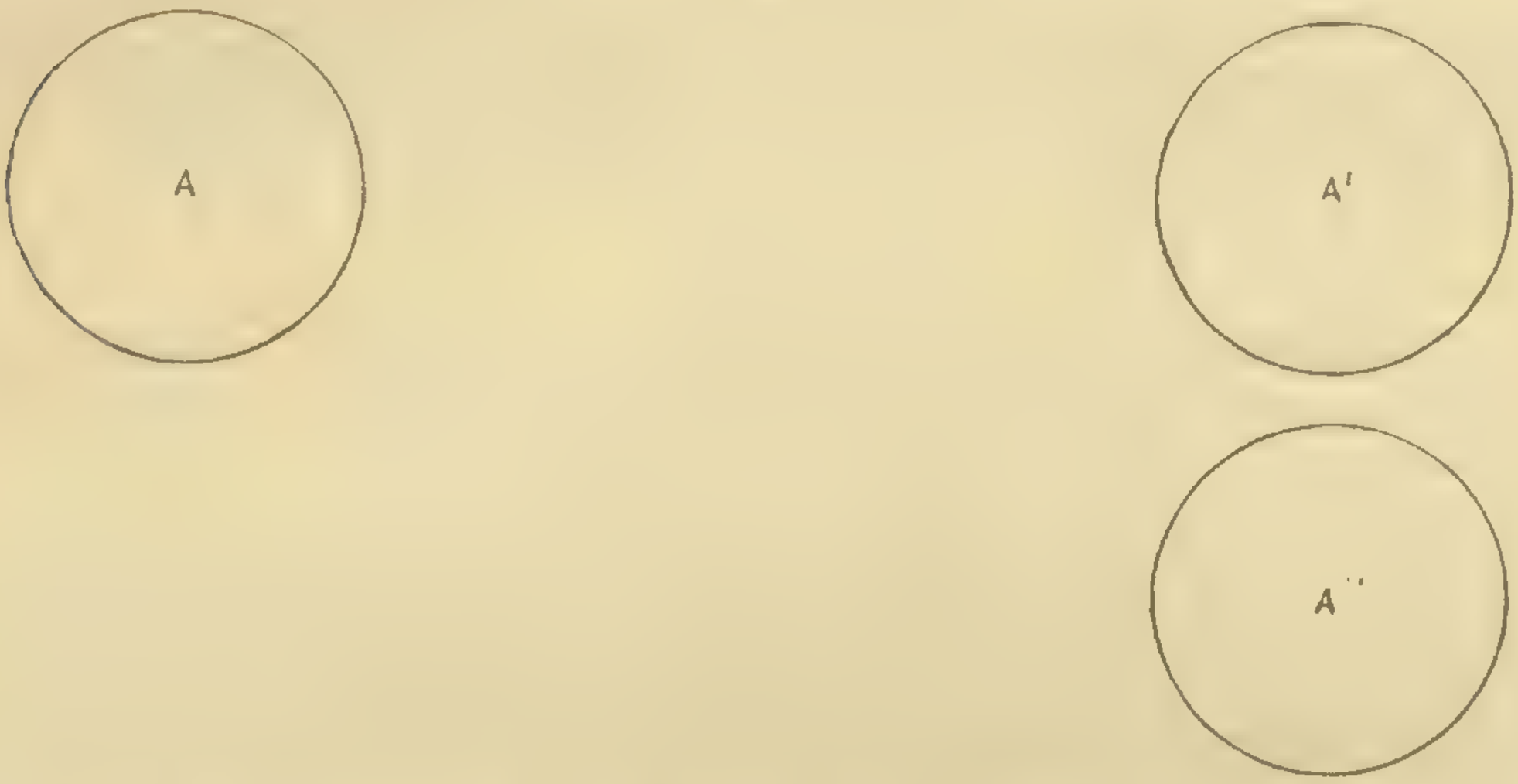
2.

retinal points; the external projections of them hence appear separate and without relief. For the subjective binocular eye (fig. 2), the two visual lines are combined into the median line cM. By indirect vision, the image of A appears on the right of the median, and that of A′ on the left, each diminished in size on account of the disturbance of ordinary retinal sensation by strong muscular contraction. This apparent diminution is greater than

* Philosophical Magazine, 1852, p. 508. † This Journal, Dec., 1881, p. 450.

can be explained by encroachment of diffusion circles at the edge of the retinal image, or on the supposition that the antero-posterior diameter of the eyeball has been slightly diminished by pressure on opposite sides of its elastic sclerotic coat. For reasons already given, the apparent distance is not very determinate. Without changing the convergence, let the eyes be rolled to the left until A′ is seen with the left eye in the direction of its visual lines. The image of A, seen still more obliquely, now appears slightly larger and dimmer, while A′ is still smaller. The apparent variation in size is thus independent of binocular combination.

3.



In such experiments one great advantage attained by using Wheatstone's stereoscope is, that by keeping the plane of each picture perpendicular to the arm that carries it, any distortion of perspective that might be due to changing the direction of the visual lines is reduced to a minimum. Making allowance for such disturbance, the visual effects just described may be obtained by means of fig. 3. A pair of circles, 2^{cm} or 3^{cm} in diameter are drawn 8^{cm} or 10^{cm} apart, their centers, A and A′, being similarly marked. Below A′ is another circle A″, equal in size. By cross-vision the images of A and A′ are combined, forming a diminished ellipse, each circle being seen obliquely; the minor axis is parallel to the interocular line. The monocular images on the two sides are sensibly circular, and larger than the central image, but smaller than either given circle as seen by normal vision. Even though distinct vision be attained under these conditions, the ciliary muscles are in a state of strong involuntary contraction. On closing one eye, these muscles become relaxed, while the direction of the visual line for the eye remaining open is easily kept unchanged. The elliptic image then apparently recedes, and in doing so it grows larger: but an interval of one or two seconds may elapse before normal monocular vision is restored. This process can be

reversed and made as gradual as is desired by slowly increasing the convergence of visual lines and carrying it beyond the point necessary for mere binocular combination. If the pair of circles just mentioned be employed, as soon as double vision is produced, the two interior images are perceived to be smaller than the others. They continue to grow smaller and apparently nearer to the observer until they coincide in the middle, and the diminution continues after they have been made to pass each other. In fig. 3, these phenomena may be noticed if the reader will combine the images by cross vision, placing the face as near as possible to the page. The angle of convergence should be at least 60°. The elliptic monocular image of A″ is perceived as suspended in mid-air. Its apparent position is not quite so nearly determinate as that of the binocular image above it, but it appears about as small and near. The left eye image, seen by indirect vision, has a much greater apparent area than the right eye image seen by direct vision.

In connection with the phenomena of optic divergence, this series of experiments proves that not only is convergence of visual lines not necessary for binocular vision and for the localization of objects in the field of view, but binocular vision itself is not necessary for the production of change in such localization. The mental impression received from the binocular image is clearer and the resulting judgment is much more definite, but no geometric method of determining the place of the external image is capable of covering the facts.

The experiments described indicate a closer connection between the nerves of the ciliary muscle and those of the retina than has been commonly supposed. Through the sympathetic system of nerves the mere action of light on the retina excites reflex muscular contraction of the iris. Without the agency of light, this may be effected by ciliary contraction alone, which is always accompanied with diminution in size of the pupil. It is by no means impossible that, through the sympathetic system, ciliary contraction should modify also the impression conveyed to the brain from the retina, while the size of the actual retinal image is unchanged. The interpretation is dependent upon the excitement of several different nerves; the thing interpreted is the product of forces from without that operate in accordance with well known mathematical laws. Helmholtz has determined approximately the velocity of propagation of a nerve impression, but beyond this there has been little success in bringing the physiology of sensation within the domain of mathematical law.

3. Relation of Axial Adjustment to Focal Accommodation.

The focal and axial adjustments of the eyes being necessarily dissociated to some extent, if clear vision is had with the stereoscope, but this dissociation being abnormal, it follows that the range of focal accommodation possible for a given pair of eyes should not be the same for different values of the optic angle. To ascertain the degree of disturbance thus induced, a series of measurements has been made with the assistance of Dr. J. H. Shorter, of the New York Eye and Ear Infirmary. In the preliminary examination it was found that at the distance of 9^m it was possible to read Snellen's test-type intended for average vision at 6^m. By the usual formula, therefore, my acuity of vision is $\frac{9}{6}$. With visual lines approximately parallel, there is hyperopia to an extent not exceeding one dioptric.* This is capable of correction, therefore, with a bi-convex lens whose focal length is 1^m. But when the visual lines are diverged 5°, latent hyperopia to the extent of nearly one dioptric more is revealed by the use of appropriate test-lenses, while the near-point of distinct vision is found, by means of test-type, to have receded proportionally. This fact could not well have been ascertained otherwise, except by the use of atropine, with its well known disagreeable consequences. The experiment shows that, in the present case at least, full relaxation of the ciliary muscles is not attained by making the visual lines parallel. For emmetropic eyes it is usually assumed that the passive condition is that of parallelism. The theory of negative accommodation advanced by Von Graefe† and Weber has not been generally accepted.

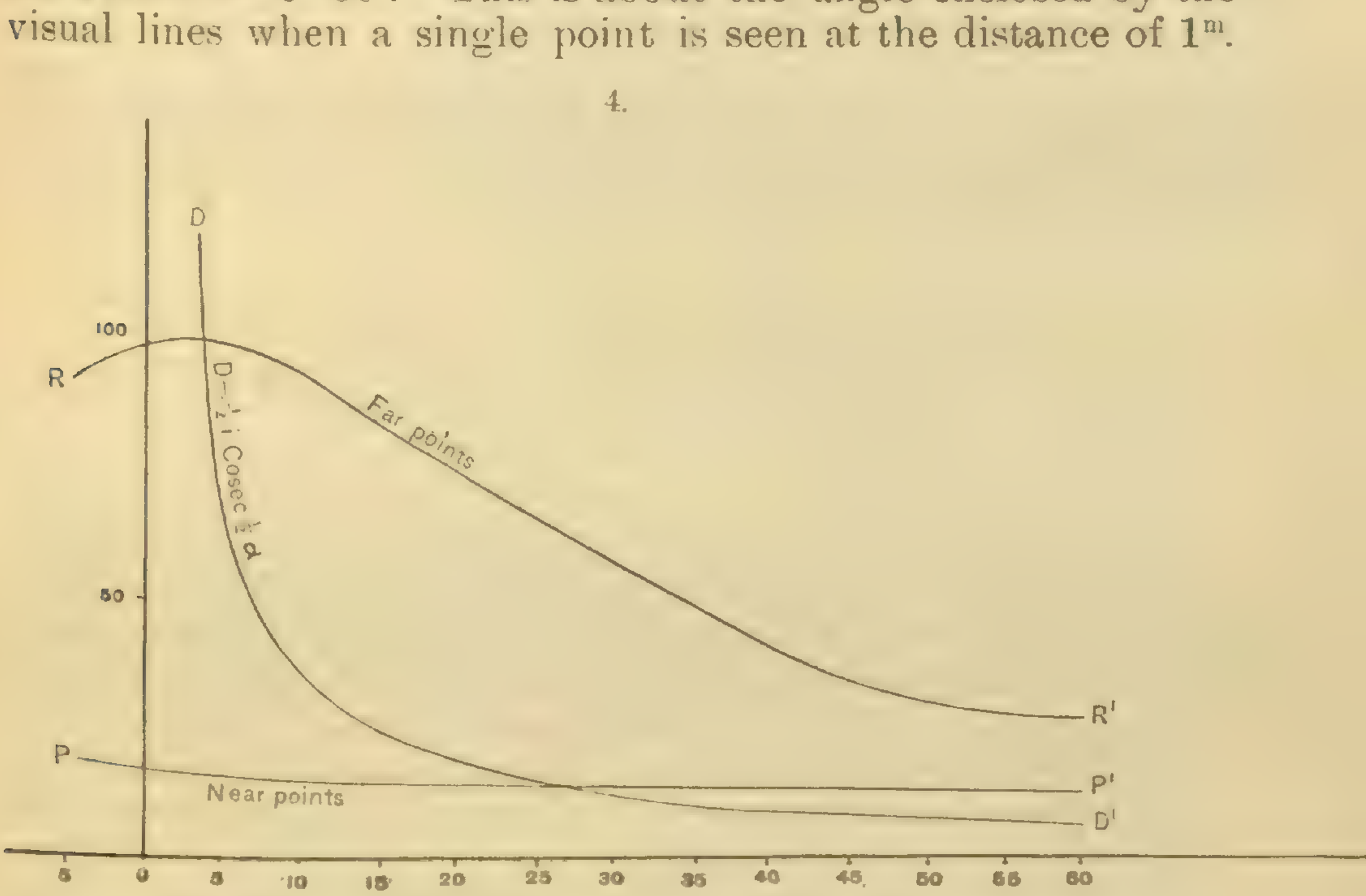
In experimenting upon range of accommodation I employed a pair of narrow cards on which were vertically printed similar specimens of test-type, intended to be read with average acuity of vision at the distance of 67^{cm}. On a large sheet of paper, covering a table, a median line was drawn, terminating at the edge in front of the mid-point between the eyes. Making due allowance for the distance of these from the edge, pairs of lines were drawn, along which the visual lines could be directed at will. Upon them the cards were placed so that binocular fusion of images could be secured for fixed values of the optic angle, to which the directions of the lines had been adapted. Along these the cards were made to recede and approach until the farthest and nearest points were found at which distinct binocular vision was possible. myself being kept ignorant of the record taken until the whole series of measurements had been completed.

* For dioptric system of measuring the refraction of the eye, see Carter on Eyesight, pp. 43–47; Macmillan. 1880.

† Soelburg Wells, Diseases of the Eye; Appleton, 1881.

The result is shown in the upper and lower curves of fig. 4, in which distances are expressed in centimeters, for successive values of the optic angle, taken as abscissas; RR′ is the curve of far-points, PP′ that of near-points, and DD′ that of distances of the optic vertex determined by the intersection of visual lines. The latter curve crosses PP′ near the point corresponding to $\alpha = 25°$, showing that, for values of the optic angle greater than this, distinct vision of an object as near as the optic vertex is impossible. This limiting value of the optic angle becomes still smaller with increasing age. The range of available accommodation in the present case is seen to be greatest when $\alpha = 3° 30'$. This is about the angle enclosed by the visual lines when a single point is seen at the distance of 1^m.

4.



At $\alpha = -5°$, the increased dilatation of the pupils, which accompanies relaxation of the ciliary muscles, reduces acuity of vision slightly, while the corresponding flattening of the crystalline lens causes recession of the near-point. The available accommodation is hence diminished, while the total accommodation remains unchanged, the portion lost by hyperopia being thus not available when convex glasses are not used. As the optic angle increases beyond $3° 30'$, the distance of the far-point rapidly diminishes, so that, at $\alpha = 60°$, more than three dioptrics of temporary myopia have been induced. It was found that at $\alpha = 4°$, the weakest convex lens impaired vision; this amount of convergence is hence sufficient to completely mask my hyperopia, stronger convergence much more than masks it, parallelism makes it manifest, while divergence reveals that which is latent

and not otherwise discoverable except by temporarily paralyzing the ciliary muscle.

4. Relation of Pupillary Area to Axial Adjustment.

Pupillary change usually accompanies change of accommodation, though not an exact index of it. During the recent experiments measurements were made of the diameter of the pupil, the intensity of the light being kept as nearly constant as possible. When axial convergence takes place, the objects being as far as can be seen distinctly, the pupils first contract, then relax perceptibly, but do not recover their previous size even after binocular vision seems perfectly distinct. When axial divergence takes place, the objects being near, the pupils dilate noticeably, and then diminish very slightly. From the following table of measurements it is seen, on comparison with the curves of fig. 4, that for the near-point, when $\alpha = -5°$, the pupil is larger than for the far-point when $\alpha = +3° 30'$. If α exceed $45°$ there is no perceptible variation of the pupil when far-point and near-point are successively regarded.

Pupillary areas, in square millimeters.

Optic angle,	$-5°$	$+3° 30'$	$+25°$	$+60°$
Maximum area,	12·4	7·0	3·0	1·2
Minimum area,	8·2	4·2	1·7	1·2

For a given value of the optic angle it is quite probable that pupillary variation is proportional to change of ciliary contraction; but the table shows that it is much limited by association with variation of contraction in the rectus muscles. The dissociation between focal and axial adjustments is but rarely complete when the convergence is strong. If diffusion circles on the retina are very small, while the image is bright, we easily fail to notice them, and it is not easy to determine when perfect distinctness of vision passes into slight indistinctness. The range of perfect accommodation is doubtless much narrower even than is indicated in the curves of fig. 4, granting that the observer's eye is perfectly free from such defects as would produce permanent error of refraction. Since the size of diffusion circles depends upon the area of the pupillary opening as well as upon error of refraction, permanent or temporary, and since distinctness of focalization is indispensable to success in binocular vision, either with or without the stereoscope, the bearing of these experiments upon the theory of binocular perspective is obvious. Though many of them are straining, they are performed to some extent, more or less unconsciously, by every one who uses a stereoscope that is ill-adapted to his eyes and stereographs that are improperly mounted.

5. The Operation of the Will in Vision.

In reference to the operation of the will upon the muscles of the eyes, Helmholtz states that we are limited to efforts for the attainment of single and distinct vision. The French edition of his great work on Physiological Optics received the last corrections of the author, and from this the following quotations must be made:

"Il faut remarquer en général que, dans toutes les mouvements volontaires, notre volonté ne tend jamais qu'à atteindre un résultat extérieur nettement déterminé et perceptible par lui-même."—*Opt. Phys.*, p. 613.

"Il résulte de ces faits que la relation qui existe entre les mouvements des deux yeux n'est pas commandée par un mécanisme anatomique, mais qu'elle se modifie, au contraire, sous l'influence de notre volonté; la seule limite réside dans le fonctionnement de notre volonté que nous ne savons pas appliquer à un but autre que celui de voir les objects simples et nettement."—*Opt. Phys.*, p. 617.

The experiments just described show that the will may be directed to the attainment of other ends than single and distinct vision. Although not affected with any paralysis or other weakness of the muscles of the eyes, and hence never troubled with involuntary double vision, I find it quite possible at any time to converge or diverge the visual lines without using any external points of fixation, thus securing two separate monocular images of a given object, keeping these apparently separated at any desired angle within certain limits, and fixing the attention alternately upon either image separately, at pleasure. A door knob, for example, may be distinctly seen double by diverging the visual lines a few degrees, and either separate image may be thus examined. Discarding the use of one eye, this externally projected image may be varied at will, in sharpness of definition, apparent size, and apparent distance, by strong voluntary ciliary contraction. This power was of course never suspected until revealed by special experiment; but there is no reason to suppose that it is not possessed by most others whose eyes are healthy.

6. Binocular Vision and Binaural Audition.

The discoveries in reference to binaural audition, made during the last few years independently by Professor Silvanus Thompson,* of England, and Professor A. M. Mayer, of this country, are interesting, not only as additions to our knowledge of physiological acoustics, but also in relation to the phenomena of

* Philosophical Magazine, Oct., 1877, Nov., 1878, and Nov. 1881.

physiological perspective. The localization of sounds has been found to be much affected by the mode in which the waves are conveyed to the separate ears. The same tone may be perceived as if produced at the back of the head, or from the two sides, or from a point obliquely in front, while the position of the true external source is unchanged, the perception being involuntary while the conditions are adjusted at will. The judgment of distance by the ear is far more uncertain than by the eye, there being no other criterion than the degree of energy of the vibrations which give rise to sensation; but the perception of direction may be modified by imposing special conditions, such as fatiguing one ear with a given tone and then listening to the same with both ears. For a fixed position of the eye, the perception of direction may be modified at will by methods already described, or by pressing upon the eyeball, while that of distance is also subject to variable conditions. Although the binaural estimate of direction and distance may be made less uncertain by properly adjusting the position of the head to the wave front, or, as in the case of the lower animals, by directing the two ears at will toward the source of sound, no one has attempted to apply geometry to the binaural localization of sounds. Its application to binocular vision is now found to be wholly unreliable in the very department for which it was deemed most satisfactory, that of stereoscopic perspective.

7. Effect of Experience in Vision.

Assuming that focalization is distinct, the position of the external focus, conjugate to that on the retina, is calculable, but for distances exceeding a few metres the variation in thickness of the crystalline lens becomes so slight that as an element in forming judgments of distance it may be practically discarded. We are justified in saying therefore that there is generally no recognizable relation between the character of a retinal image and the distance of the object pictured, any more than between the composition of a sound image and the position of its external source, except so far as personal experience serves to establish it. Experience, both visual and auditory, begins in infancy, long before the power to analyze sensations is developed, and in putting an interpretation upon these, association is the chief determinant. Strong contraction in the ciliary and internal rectus muscles is unconsciously associated with nearness of the point of fixation, and this is pictured upon the yellow spot of the retina. No one whose eyes are healthy has any consciousness of possessing any retina except in relation to external objects, or any tympanum except in relation to

aerial disturbances, or any ciliary or rectus muscles except in relation to variation in position of the point on which attention is fixed through the medium of retinal sensation. We might expect therefore that unusual muscular conditions would cause misinterpretation regarding the whole field of view, but especially those parts which correspond to that portion of the retina which is most frequently impressed and most sensitive. Under strong muscular contraction, arousing abnormal vision, it is hence not remarkable that an object pictured on the central part of the retina should be misjudged as smaller and nearer than one of the same real size and distance pictured upon marginal portions; and that the illusion should disappear as soon as the muscles are relaxed and normal conditions thus restored.

There is one psychologic aspect of the present investigation of which I have not been unmindful, particularly in reference to the effects of extreme voluntary ciliary contraction. In recording the results of even normal vision every astronomer applies what experience has taught him to be his personal equation. In the present experiments in abnormal vision, some of which are not easy, the personal equation cannot well be ascertained. While there has been given what I believe to be a correct account of phenomena actually observed and not consciously anticipated by myself, there must remain, for a time, an element of uncertainty, how much may be due to personal peculiarity and how much to qualities belonging generally to the human eye. The most careful of observers may be occasionally mistaken in attributing to physical conditions what is really the subjective effect of unconscious expectant attention. The very consistency of these phenomena with the empirical theory of vision might cause a predisposition to certain perceptions that might not be so successfully attained by one who is thoroughly committed to the opposite school of thought.

8. Theories of Binocular Perspective and Relief.

The reasoning already expressed suggests additionally the futility of attempting to refer our binocular perceptions exclusively to any single condition such as the external intersection of visual lines or the internal recognition of double images in one part of the field of view while another part is scanned, applicable as these conditions may be when considered simply as elements that may at times enter into our interpretations. In their application to stereoscopy the physiological elements of perspective imply no contradiction to the laws of mathematical perspective which must be applied in constructing the stereo-

graph. The relative distances in the drawing being fixed, variation in muscular sensation may modify the imagined scale of measurement, while ratios are sensibly the same as before. The beautiful results attained by Professor W. B. Rogers* in determining the form of the binocular resultant are applicable to projecting lines that intersect, and not necessarily to visual lines, since the perception is attained when these are divergent. The same remark is true of Helmholtz' admirable mathematical discussion† of the stereoscope, in which he makes no provision for optic divergence, although elsewhere he refers to the possibility of stereoscopic vision by this method. It is but due him to state that, under the conditions assumed, he closes his discussion with the remark, "These conditions are not always fulfilled for the photographic proofs and the stereoscopes of commerce."

Associated muscular action, to which special prominence has been assigned in the present series of papers, is in like manner incapable of explaining all the phenomena of stereoscopy. Much stress has been laid upon it because it covers all the facts that have hitherto been referred to visual triangulation, and additionally those of optic parallelism and divergence, assuming that the stereoscopic displacement on the card is large enough to permit the perception of double images in the background when the foreground is viewed, and that the time of illumination is sufficient to allow free play of the eyes. The perception of stereoscopic relief is possible when the stereoscopic displacement is so minute that no sensible motion of the eyes is possible and no duplication of any points in either foreground or background can be perceived with even the keenest vision. The stereograph has been repeatedly examined, and relief distinctly perceived, successively with natural and reversed perspective, when illuminated by the electric spark, the duration of the retinal impression being thus reduced to a minute fraction of a second. Undoubtedly the play of the eyes often enables us to become at once sure of interpretations that would be enveloped in uncertainty until after several trials by momentary illumination. In ordinary vision we rarely ever notice the duplication of images on the hither and farther side of the point of fixation, partly because the attention is apt to be confined to the point fixed, but also because other points are not distinctly focalized upon the retinas, and the majority of these imperfect images fall on retinal parts that are not central and hence are deficient in sensitiveness.

It has been suggested‡ that the perception of relief is *by*

* This Journal, II, vol. xxi, pp. 91, 173, et seq.
† Optique Physiologique, p. 842, et seq.
‡ LeConte, Sight, p. 151; Appleton, 1881.

means of double images, and that the mind *instinctively* distinguishes between those made by objects that are respectively farther and nearer than the point fixed. This last proposition would be hard to demonstrate experimentally, but even when the attention is not specially given to the double images, these may, and probably do, play an important part as elements in the unconscious formation of judgments. Again it has been stated* that we see *at long and short distances at the same time*, because the retina has thickness and transparency, and images are focalized at different depths beneath its surface. Here again we can neither affirm nor deny in answer, although recognizing the fact that the crystalline lens, being one of short focal length, has in consequence of spherical aberration considerable "depth of focus." It is moreover fluorescent, irregular in structure, and imperfectly centred. Perfectly sharp focalization is hence impossible, as shown in the radiated appearance of stars and the irradiation about any brilliant surface like that of the crescent moon. These optical defects may be in some respects advantageous in ordinary vision. If Towler's theory be true, though not demonstrable, it may partly explain the possibility of binocular combination when the differences between the two pictures are so minute that the perception of double images in any part of the binocular field is impossible. Some idea can be formed of the minuteness of the stereoscopic displacement actually necessary when we consider that Mr. Warren De la Rue succeeded in obtaining a stereograph of the sun, from which by stereoscopic vision, the ridges of the faculæ could be perceived in sharp relief. On the stereograph of the moon, to which reference has been more than once made, the elevation of mountain ranges and solitary peaks, and even the inequalities of the supposed dead sea bottoms can be clearly seen. The crater Copernicus and the lunar Apennines stand forth particularly boldly, and the ridge that divides the bed of the heart-shaped "Sea of Serenity" can be easily traced. Any one who has undertaken the preparation of a stereograph with the pencil or pen knows how very difficult it is to avoid the production of roughness in the combined image at places where smoothness is desired. No two impressions from the same type can be taken that will not present some inequalities when stereoscopically examined, and no two groups of type representing the same sentence can be so accurately adjusted as not to betray imperfection when subjected to this searching test.

In what has been said of "corresponding retinal points," no mathematical meaning has been assigned to this expression, and obviously none can be. It is generally thought, but has not been experimentally demonstrated, that each rod or cone on

* Towler, The Silver Sunbeam, p. 310; E. & H. T. Anthony, 1879.

one retina has its mate in the other, and when such a pair are simultaneously impressed they convey but a single impression to the brain. If in each eye the retinal image is so small as to cover but a single rod or cone, we have thus the so-called *minimum visibile*, and by calculating the retinal area corresponding to the smallest object that can be separately seen at a given distance the diameter of such a retinal element has been estimated. There are strong reasons however for doubting the validity of this theory of corresponding retinal points. All we can affirm is that experience, acquired individually and probably with exceeding rapidity in consequence of inherited tendencies, has taught us to interpret retinal sensations that are slightly different in the two eyes, as the signs of an external object possessing three dimensions in space, when the images are made upon parts of the concave surfaces that bear to each other the mathematical relations imposed by the presence of such an object in normal binocular vision. Sensation is never confined to a point, or pair of points, but only to areas. If we grant the correspondence between small retinal areas, simply as the result of experience rather than as a truth in anatomy, it is not hard to understand how a pair of slightly dissimilar images may produce upon the brain a modified impression, even when no duplication in any part can be perceived. It may be quite possible for the *quality* of a retinal sensation to be modified while the additional impression, apart from that which it modifies, would be imperceptible. From what we positively know regarding sensation in the ear, we are justified in applying similar reasoning tentatively to sensation in the eye.

It is well known that no perfectly simple sound is produced by the voice, or indeed by any musical instrument; but that the difference in quality between two tones nominally the same from different sources is due to minute modifications upon sensations, corresponding to attendant waves, most of which are too faint to be perceived without instrumental aid. A well trained ear however is able to pick out some of these overtones, even when two different voices are singing nominally in unison. The brain of the listener receives two sound-images, each complex, that approximately coalesce. By special attention he singles out a few musical salient points and thus perceives double images in the background; but the great majority of the attendant modifying tones are so faint and so inextricably mixed together that it is impossible to do more than perceive their resultant effect upon the fundamental about which they are grouped. The rich combination of all stands out in strong musical relief, when compared with the impression from either voice alone, or with the sweet but thin sound of the tuning fork that sings forth the same fundamental pitch.

This comparison relates to the combination of sensations, whatever may be the cause of dissimilarity among the components of the group. In the case of audition the modifications imposed upon the sensation are due to combination among waves varying in length from a small fraction of an inch to many feet. The graphic representation by curves is an arbitrary but exceedingly convenient method of indicating the quality of a sensation from what we know of the physical character of its proximate cause, however complex this may be. Waves of light are far more minute than those of sound, and we have no evidence of sensible interference among them in the production of binocular vision. We have not the data from which a binocular image can be graphically expressed as a curve, and thus compared with one of the monocular components. But the facts that are forced upon our attention suggest kinship between the *modes of sensation* in the two cases. The group of light images in the one eye forms a sum total that is different from that in the other, and the sensations they arouse are simultaneously conveyed to the brain. Experience comes to our aid, and the modified resultant is instantly recognized, even though we may be unable to perceive separately the minute modifications which give character to the two main components that form it.

I doubt therefore the anatomical theory of corresponding retinal points, and regard that of partially correspondent retinal areas as a substitute more in accordance with observed facts. This correspondence moreover must be considered merely the effect of association resulting from oft repeated experience, an association that is very quickly established, although a newborn infant does not seem to possess the power of single vision at birth. Such retinal areas should be considered as not sharply defined, as is shown by the phenomena of irradiation. A point impressed becomes the center of a minute area of disturbance, just as on the skin a point pricked with a pin is a center from which pain is quickly extended to an area. A group of such retinal areas are of necessity partially coalescent. The absence of sharp definition on the retina is one condition on which stereoscopy becomes possible through the apparent blending of images that are really dissimilar. If the dissimilarity is but slight, clear relief is perceived without the production of any sensible duplication of images in any part of the binocular picture.

In the light of these facts it is seen that the explanation of stereoscopy with perfectly similar figures, as given in my last paper,* was incomplete. It was known to be so at the time it was given, but my intention was to present only a geo-

* This Journal, April, 1882, p. 297.

metric discussion and reserve the remainder for a new paper. In performing the experiment for the first time, confusion is generally experienced; after a few moments the form of the binocular resultant is clearly perceived, and in subsequent trials the perception is attained much more quickly, all parts of the image being sensibly equally distinct at the same moment, if the inclination of the cards be not great. It is only when this inclination is considerable that play of the eyes becomes necessary, and the associated exercise of the rectus muscles thus furnishes suggestions that are complementary to the modification of retinal impressions just discussed. There are further experiments in regard to this mode of stereoscopy by momentary illumination, which I hope to make and publish at some future time.

New York, 40 W. 40th St., April 3d, 1882.

Art. XXXVIII.—*On the Flood of the Connecticut River Valley from the Quarternary Glacier*; by J. D. Dana.

[Continued from page 202.]

The facts, presented in the preceding part of this paper, on the dimensions and velocity of the flooded Connecticut appear to make it certain that, during the era of the great flood, the pitch of the Connecticut valley was very much less than it is now, and that a change equivalent to 1 foot a mile from the Sound to Springfield, and 2½ feet a mile to Haverhill (and an undetermined distance beyond)—but corresponding to some curving plane between the extreme points—would not be too great to meet the requirements.*

But I have not said that the land over the interior of New England was depressed to the amount stated, or to any amount. It has been left an open question whether the change was a change in the sea-level or in the land-level.

Leaving this point for discussion in another number of this Journal, I here take up the subject of the disappearance of the ice from the Connecticut valley.

5. *The Retreat of the Glacier.*

The *rate* of retreat or disappearance of the ice along the Connecticut valley and from the Connecticut River drainage-area had a relation to the amount of discharge of the flooded river; and the time required for the retreat a like relation to the amount of ice to melt. But there are various unknown

* This curving plane would make right the heights for Middletown and Springfield on page 199, where the former is, by the assumed rate of pitch, the higher.

quantities connected with this subject, and only some very general conclusions can be looked for.

(1.) *Drainage-area.*—The present drainage-area of the Connecticut, north of Massachusetts, covers about 8,500 square miles; between the northern Massachusetts line and Hartford, 2,100 square miles; and between Hartford and the Sound, 450 square miles; making in all 11,050 square miles. The Hartford limit is here made to extend south of Hartford on the west, so as to include the whole drainage-surface of the Farmington River, which joins the Connecticut north of Hartford. The area covered by the Quinnipiac River might also be added, since the overflows from the Connecticut River valley, at Northampton and south of this point, so far as they emptied into the Sound by a separate outlet, reached it by the Quinnipiac valley. But the area is not over 50 square miles.

(2.) *Amount of ice over the drainage-area.*—The mean thickness of the ice in and west of the White Mountain region, judging from the glacial scratches on the White Mountains, and on Mt. Mansfield of the Green Mountains, was probably about 5,000 feet; at the sources of the Connecticut River, 75 miles north, on the borders of Canada, at least 6,000 feet; and to the south near the Massachusetts border, not far from 3,500 feet. The mean thickness for the whole area, 8,500 square miles in extent, thence deduced, is about 4,500 feet; and, if so, the whole amount of ice covering the drainage-area north of Massachusetts, at any one time before melting had made much progress, would have been about 7,250 cubic miles.

Over the more southern part of the drainage-area, 2,550 square miles in extent, the mean thickness was probably near 2,000 feet. In this the thickness along the north shore of Long Island Sound is taken at 1,000 feet; and it is put at this figure rather than lower because the glacier continued flowing southward and eastward for at least 34 miles, it having extended across the Sound, and landed large bowlders, some of more than a hundred tons weight, with a large amount of moraine material (referred to the terminal moraine) on the south side and other parts of Long Island: and the chief part of the fall necessary for motion came from a northward increase in the thickness of the ice, the Sound being a shallow trough 20 miles or so wide. A slope of 0° 25′ would give a pitch of 38·39 feet per mile (= 1 : 137·5), and make the thickness along a line 34 miles north-northwest from the south side of Long Island, 1305 feet; and one of only 0° 20′ would give a pitch of 30·72 feet per mile (= 1 : 171·8), and a thickness of 1,044·5 feet.* On the above assumption the amount of ice in this part of the drain-

* In Greenland a thickness of more than 900 feet exists according to Helland, at the very end of the Jakobshavn glacier, this being proved by the thickness of the icebergs broken from it.

age-area at any given time would have been 965 cubic miles, making the total about 8,215 cubic miles.

(3.) *Sources of the Water.*—Melted ice and unfrozen waters from the precipitation over the drainage-area were the sources supplying the flooded streams.

The precipitation, to produce the snows needed for the Glacial era, must have been large, much larger than now. The amount at the present time for the part of the drainage-area north of Massachusetts averages 42 inches a year, and for the part south, 46 inches; while on Mt. Washington, just east of the area, the annual fall is between 55 and 80 inches. In 1873, 78·56 inches were registered on Mt. Washington.

In the Glacial era the conditions must have occasioned still more abundant precipitation. The ocean was, in all probability, much warmer than now, either through the shallowing of the Arctic seas, which shallowing would have diminished much the southward currents of cold polar water, and also the extreme northward flow of the Gulf Stream; or in some other way. In addition, the border region of the continent, in these and higher latitudes, had not merely snow-clad heights, but ice-made heights, from the sea-margin to the top of the lofty ice-range. Moreover, the region of New England was within the more seaward portion of the icy slopes.

The relations were consequently like those between the tropical Indian Ocean and the seaward mountain ridges of India, though less extreme. In India, at many localities, the mean, annual rain-fall is 100 to 160 inches, while at three stations on the Ghats, in Bombay, it is over 250 inches, and at one in Assam, nearly 500 inches. In such facts we have seemingly sufficient reason for estimating the average annual rain-fall of the Connecticut valley during the Glacial era to have been at least as high as 120 inches. The present high average on the isolated White Mountains is good evidence that 90 inches would be too small an estimate, and the more so since during the four months in which half of the precipitation there takes place, June, July, August and September, the slopes are, with small exceptions, free from snow—Mr. Schott's tables (page 56) making the mean for the four years of observations 67·12 inches, and for the four months just mentioned, 33·83 inches.

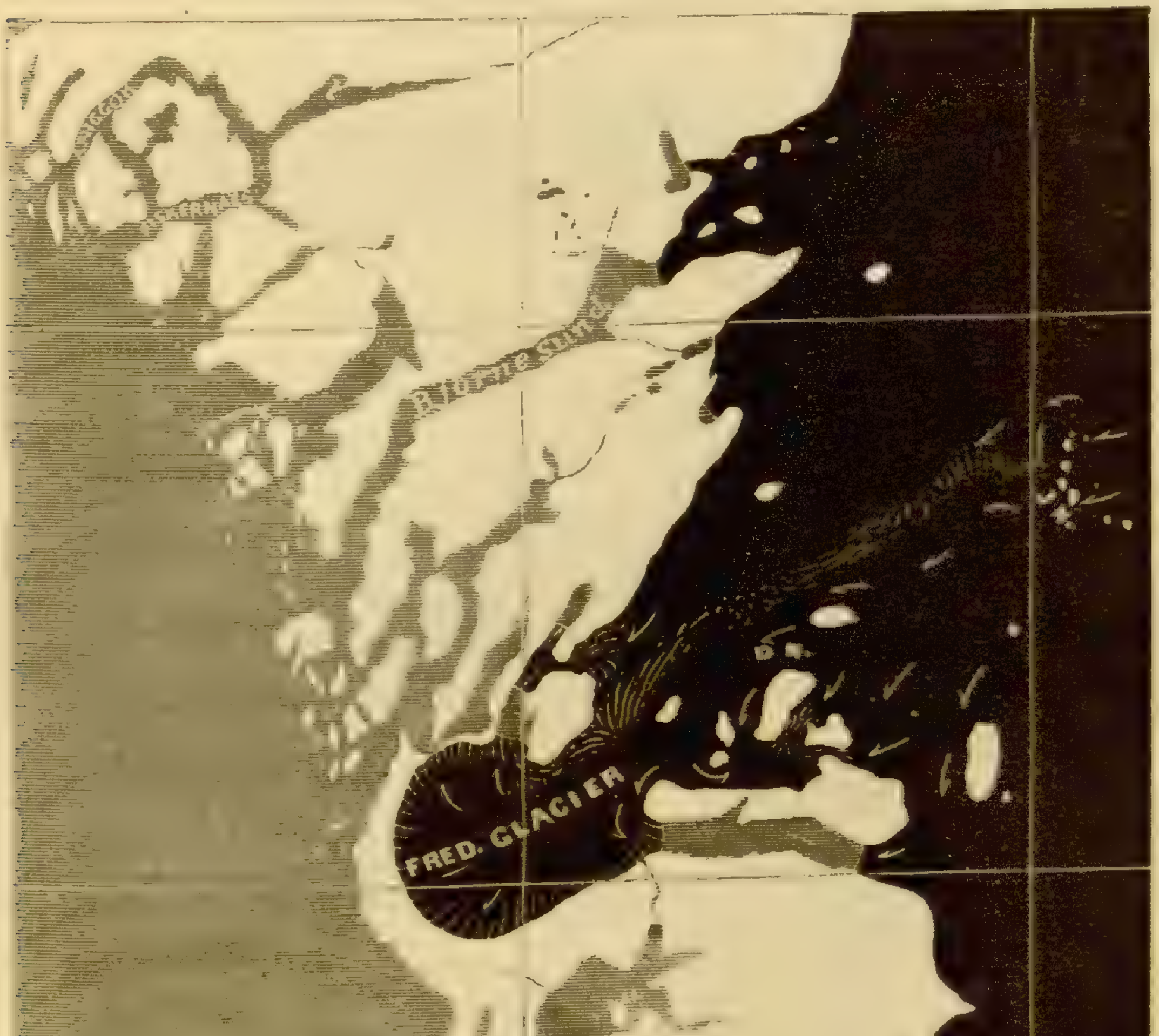
The facts make it apparent, whether the above estimate be precisely right or not, that the amount of precipitation was far greater than in any modern glacial region. And the same must have been true for the southern portion of the ice-slope, *west* of New England, over which would have blown moisture-ladened winds from the region of the great Mediterranean sea of the continent; though possibly, owing to the distance from that sea and the position of the Appalachians, the annual precipitation

north of the Ohio may have been increased somewhat less than over New England.

From the condition of Greenland,*—a semi-continent, covered by a continuous glacier-mass more than a thousand miles long

*The chief sources of information with regard to the interior of Greenland are: (1) the exploration, in July, 1870, of Nordenskiöld over the ice for 28 miles, sixty miles south of Jakobshavn, near the parallel of 68° 20′, (*Geol. Mag.* for 1872); and (2) that of Lieutenant J. A. D. Jensen, in 1878, with Mr. A. Kornerup as geologist, who started on the Frederikshaab glacier, between the parallels of 62° and 63°, and traveled 47¼ miles in an E.N.E. direction (*Meddelelser om Grönland*, Copenhagen, 1879, Part first).

1.



The black part, ice; white, land; shaded, water; J. N., Jensen's Nunataks; D. N., Dalager's Nunataks; white lines on the black, crevasses; arrows, glacier-flow.

Nordenskiöld saw an undulating surface of ice, white and moraineless, much intersected by crevasses, and furrowed by innumerable rivers, and one "copious, deep and broad river between banks of blue ice," whose banks he followed until he saw "the whole immense mass of water rush down a perpendicular crevasse into the depths below." There was dust over portions of the surface, and with it, as detected by his companion, Mr. Berggren, great quantities of a minute alga, in the form of threads of usually 4 or 8 cells, along with some *Protococcus nivalis*, and, in one place, so much of the material lay together, (collected by streams then dried up), that it had become putrescent in the sun, "so as to emit a most unpleasant odor, like that of butyric acid." Nordenskiöld says that the alga tend to make rapid melting of the ice under the summer's sun. The height reached by Nordenskiöld

and several hundred wide, and leaving outside only a fringe of fiords and islands generally but 30 to 60 miles in width,—we may derive many facts illustrating this subject. We learn from it that a continental glacier (1) would have crevasses of indefinite number and extent, either transverse to the direction of motion, longitudinal, or radial, according to the bottom over which it moved and the attendant conditions; that (2) it would be covered extensively, in the warmer season at least, with fresh-

was 2,200 feet, and the mean slope of the ice-surface on the way, as deduced from the height, was 0° 26′, equivalent to 40 feet per mile (1 : 132).

Lieut. Jensen, at the limit of his inland ice journey of 47¼ miles from the foot of the Frederikshaab glacier, reached a cluster of rocky peaks, rising from beneath the glacier—*Nunataks* of the Greenlanders (J. N., fig. 1). The heights above the sea of the four largest were severally, commencing to the north, 5,623 (*g*), 5,184 (*i*), 5,654 (*k*), and 5,580 (*m*), feet. (See fig. 2 below.) From these peaks, which stand like islands in the sea of ice, moraines of stones and earth (some of the stones 20 feet in their dimensions) extend for 1 to 2½ miles, (*m′*, *m″*, *m‴*, *m⁗*, fig. 2) and dust, by the aid of the storm winds, is drifted off for wide distribution over the glacier. The moraines, after a short outside existence, disappeared beneath the ice, the stones dropping down the crevasses that were from time to time opening (the account says) as the glacier moved on. The varying direction of the moraines, and the eddies in the flowing ice, due to the obstructing ridge (of which the Nunataks are the peaks), which these directions indicate, are remarkably instructive. The arrows show the inferred direction of movement. The moraine *m′*, 2½ miles long, is made mostly of polished stones, which appear therefore to have traveled far, and not to be the debris of the nunataks. The *m″* and *m‴* have no connection with any visible nunatak. At *b* is a lake 824 feet in diameter, and toward it the ice around slopes from a height of 4,900 feet to that of 4,120 on its borders. The glacier had a height at *l*, east of the nunataks, of 5,150 feet. The slope of the ice-surface for the distance traversed averaged 0° 49′, or about 75 feet per mile (1 : 70): and it was evident that the movement of the glacier depended on this slope. Crevasses were numerous along the route transverse to the line of movement as well as longitudinal and radial (see fine lines along the route on fig. 1): and fresh-water streams were common, and water-falls also.

2.

The largest of Jensen's nunataks consisted mostly of hornblende schist in bold flexures, with mica schist and gneiss. Twenty-seven species of plants were collected from them by Mr. Kornerup, and among these were the grasses *Luzula hyperborea* and *Carex nardina*, widely spread, *Trisetum subspicatum* and *Poa trichopoda* in scattered tufts; the sorrel, *Oxyria digyna*; the white-flowering *Cerastium alpinum* and *Saxifraga oppositifolia*; the little blue-flowering *Campanula uniflora*: *Potentilla nivea*, *Ranunculus pygmæus*, *Silene acaulis*, *Cassiope hypnoides*, *Armeria Sibirica*: and the yellow-flowering poppy, *Papaver nudicaule*, which was taken

water streams, ending their short career by a leap down the crevasses; and that such streams might often attain large size before making their plunge to sub-glacial depths; that (3) the melting at surface and thereby the wasting of the ice would probably have been promoted by a wide distribution of microscopic algæ; that (4) sub-glacial streams would have been numerous and large, and that they might have kept up their flow even through the coldest season; that (5) sub-glacial streams, flowing out from beneath the discharging glacier, would have transported fine earth and clay, the results of glacier abrasion,

from the top of the highest nunatak. Of these, the *Luzula*, *Oxyria*, *Trisetum*, *Silene*, and *Cassiope* are among the Arctic species left on the White Mountains, while the *Saxifraga* is found on the Green Mountains (Asa Gray.)

The fringe of fiords and islands along Western Greenland, 30 to 60 miles wide, is mostly, as figured by Dr. Rink in his Danish Greenland, outside of the great continental glacier. The discharging ice descends into the heads of the fiords and thus makes the so-called glaciers; and here, under the action of the tides on the free end where not thick enough to lie on the bottom, great masses are broken off to drift away as icebergs. This border region, in contrast with the interior just east of it, rises into numerous peaks of 3,000 to 4,000 feet, and, about Umanak-fiord, in north Greenland, there are summits of 6,000 to 7,000 feet. It is mostly free of ice below a level of 2,000 feet and partly so above this limit: yet over its higher summits there are local glaciers. Figure 1 shows,—in the part left white,—the breadth of this fiord-border north of the Frederikshaab glacier, and, also, the interior ice descending into some of the fiords to varying distances, and failing to reach others. At the south end of Greenland, the interior ice is hardly 30 miles distant from Cape Farewell, although near 60° N.

To aid the reader in understanding the conditions in Greenland, the following climatal facts are here cited from Rink: The mean annual temperature at Lichtenau, in 60° 31′ N., is 33°2 F.; at Godthaab, in 64° 8′ N., 27°8 F.; at Jakobshavn, in 69° 14′ N., 22°6 F.; at Upernivik, in 72° 48′ N., 13°3 F.; at Jakobshavn, annual range of monthly means 0°3 F. to 45°3 F., and at Godthaab, 11°8 F. to 44°4 F.; temperature of the soil, 4 feet under ground, at Godthaab varies during the year between 31°5 F. (March), and 40°1 F. (September); the height above the sea of the snow line in Danish Greenland is about 2000 to 2200 feet.

In July, 1875, Helland, of Norway, made measurements on the glacier in the Jakobshavn fiord (*Om de isfyldte Fjord og de glaciale Dannelser i Nordgrönland*, and *Quart. Journ. Geol. Soc.*, 1877, p. 142). He determined the width to be 4,500 meters, and the slope of the ice-surface to be less than half a degree. Yet the rate of motion he found to be, at middle, 20 meters per day; 400 to 450 meters from the sides, 15 meters; and close by the side, 0°2 meters per day. This rate is 15 times greater than has been observed in the Alps and needs confirmation. The rate for the smaller glacier of the fiord of Torsukatak, in 69° 50′, he made half less. The rapid flow of the former he attributes to the pressure of the mass of the interior ice.

Helland states that in his views over the interior ice from five high peaks of the fiord border, between 69° 10′ N. and 71° 15′ N., he saw only ice, like a great sea, lying at a much lower level than these peaks but rising slowly inland and forming an undulating sky-line. The surface of the glaciers in the fiords was mostly free from stones, except at the margin. At the Jakobshavn fiord the discharge of ice in July was equal to one large iceberg a day of about 16,000,000 cubic meters. The discharge continues in the winter, as the icebergs set free prove, but at a slower rate. He observes also that the amount of glacier discharged as ice is far less than that which passes out as water beneath the glacier. The mean amount of mud discharged by the waters flowing from 6 glaciers he found to be in July and August, 1875, 727 grams in 1 cubic meter of water (or in 100,000 grams very nearly). According to the fishing lines of the Greenlanders, the depth of the Jakobshavn fiord is about 390 meters, or 1280 feet.

to make aqueous deposits, which might or might not be free from stones or bowlders.

Dr. Rink, the Greenland explorer, and for many years, Government Inspector of South Greenland, states, in his "Danish Greenland," (1877) that the sub-glacial streams which flow out from beneath the ice in the ice-discharging fiords, are very copious and sometimes violent torrents, making whirlpools a hundred feet in diameter as the waters escape from sub-glacial confinement; that they probably branch widely over the country like a regular river system; and he refers to the authority of the natives, as well as to the observations of explorers. He observes that, according to his estimate,* out of the 10 inches of annual precipitation—the mean amount—only 25 per cent. or $2\frac{1}{2}$ inches, are needed to supply the loss of ice from the discharge of icebergs; and that the rest, apart from what is lost by evaporation, makes up the amount of loss from melting, indicated by the sub-glacial waters. An annual supply to this end of only 6 or 7 inches could not produce the largest of rivers.†

From these facts we may hence assume that the great glacier of Eastern North America would have had

(1) Crevasses, with only local exceptions:

(2) Surface streams flowing with nearly pure waters over nearly pure ice, suddenly becoming sub-glacial by descending the crevasses; and

(3) Sub-glacial streams as much more extensive than those of Greenland as the precipitation was more copious and the drainage-areas larger.

If in Greenland 60 or 70 per cent of the precipitation is a measure of the amount of water contributed to the sub-glacial streams, 60 per cent. may have well been the amount in New England during the progress of the Glacial era; and this, with an annual fall of 120 inches, would have been 72 inches or 60 inches with one of 100 inches. This estimate can hardly be over-large considering that tropical and warm-temperate regions were not far distant, and that the summers, if it were a fact that they were shorter than now, were proportionally hotter. When the glacier began its decline, the proportion of the precipitation becoming sub-glacial would have gradually increased, and so on to the end. And, consequently, as the amelioration of the climate made progress, the melting would have augmented in rate through the increasing warmth of the winds. The fact that glacial conditions tend to perpetuate themselves is well

* Based chiefly on the flow of ice in the Jakobshavn fiord, as measured by Helland.

† According to Helland, the mean precipitation at Jakobshavn for the year between July 1873 and July 1874, was only $8\frac{1}{2}$ inches, and for the year following, 7 inches.

illustrated in the present state of Greenland. But in North America, situated on the wind-receiving side of a warm-temperate and tropical ocean, whose tropical waters lay against its southern border for more than a thousand miles, the strength of the tendency would have been severely tested.

Pressure and friction would have been other sources of melting; and perhaps, in view of the breadth of the area covered by the glacier, some small amount may have been occasioned by subterranean heat.

(4.) *Mean annual discharge of the Connecticut River at the time of maximum flood.*—The data for calculating the amount of discharge of the flooded river are: (1) the estimated mean width of the river, 2,500 feet, (the reduced estimate); (2) the mean depth, 140 feet; and (3) the mean velocity, which we may take at 3 and 4 miles an hour. The length of the river from Wells River to the Sound is 200 miles. Hence, $66\frac{2}{3}$ hours for 3 miles an hour, and 50 for 4 miles, would have been required, to pass into the Sound the waters, that at any one time occupied the channel.

The estimate of 140 feet for the depth can hardly be too great, seeing that the highest terraces are, at the south, 200 feet high above modern low-water; and to the northward, 200 to 265 feet. The view that the range of upper terraces, including the so-called delta-terraces, mark approximately the high-water level, is the common one with all that believe the terraces to be of fluvial origin; and I feel under obligation to add, inasmuch as the different idea about the "normal highest terraces" and the "delta terraces" of the Connecticut, opposed in the earlier part of this paper, is from one of the New Hampshire Geological Reports, that this accepted view is that sustained and taught by Professor C. H. Hitchcock, the head of the New Hampshire Survey.

The amount of water lying in the channel at any one moment would have been 2·511 cubic miles; and the daily discharge, if the velocity were 3 miles an hour, nearly 0·9 (0·904) cubic miles: or if 4 miles an hour, nearly 1·2 cubic miles (1·205). At the two rates of flow mentioned, the amount of water discharged during a year would have been about 330 and 440 cubic miles.

(5.) *Annual loss of ice from the melting.*—Now comes the question how much of this water came from the melting glacier-ice, and how much from the cotemporaneous precipitation; or how much did the amount of water exceed the amount of precipitation?

If all of the water came from the ice, the amount of ice melted—taking its specific gravity at 0·92—would have been,

at the two rates of flow in the river, about 359 and 4785 cubic miles.*

The amount from the precipitation to be deducted does not diminish greatly these numbers, even if all of it went to increase the floods. With a mean annual rain-fall of 120 inches, or 10 feet, this amount for the part of the entire drainage-area north of Massachusetts, would be only 16·1 cubic miles; and for the whole drainage-area to the Sound, 21·8 cubic miles.

This amount, 21·8 cubic miles, is too large by the amount which would have been lost through evaporation, soil-absorption, chemical changes in and beneath the glacier making oxides and hydrates, and in other ways. An estimate of these losses may be derived from the modern Connecticut.

The annual discharge of the Connecticut, as determined by measurements made under the direction of General G. K. Warren, of the U. S. Engineer Corps, by General T. G. Ellis,† at Hartford, Ct., where low water in the stream is almost exactly mean-tide level, it being only ·045 feet below it, was as follows for the years mentioned:

Year.	Discharge in cubic feet.	Year.	Discharge in cubic feet.
1872	638,070,000,000	1875	570,649,000,000
1873	727,160,000,000	1876	706,291,000,000
1874	733,103,000,000	1877	526,261,000,000

The largest of these sums, that for 1874, corresponds nearly to 5 cubic miles (more exactly 4·98).

The amount of annual precipitation over the drainage-area *north of Hartford* to the sources of the Connecticut (allowing 42 inches as the mean for the part north of Massachusetts and 46 inches for the rest north of Hartford), averages nearly 7·17 cubic miles. Consequently the amount discharged at Hartford in 1874, was 69·5 per cent of the precipitation; so that the loss in all other ways was little over 30 per cent. In 1877, a year of minimum discharge, the amount was 50 per cent.

The proportion of 70 per cent more correctly represents the condition in the era of the glacier-melting than that of 50: for it is the proportion during a year of great Connecticut floods: and these floods are dependent, in nearly all cases, (1) on the large amount of snow and ice of the winter or spring season, and to a considerable extent (2) on the frozen state of the ground over the hill slopes and much of the country, favoring an easy slipping of the waters over the surface without absorption by the soil,—conditions eminently characteristic of the era of the

* The specific gravity is here taken too high because of crevasses and want of compactness of glacier-ice; but this error, for the calculation of which no specific data exists, is not here of importance. Helland found the specific gravity of the ice of a large iceberg only 0·886, this low rate being due to linear air bubbles which thoroughly permeated it.

† Annual Report of the Chief of Engineers for 1878. Appendix B 14.

Glacial flood. This point is further exhibited in the following table, in which the monthly discharge of the Connecticut at Hartford, for the years 1872 to 1877, is given from General Ellis's Reports; and also the rainfall (snow included) for the same years at Lunenburg, Vermont, two miles west of the Connecticut, in lat. 44° 28′ N., long. 71° 44′ W., at a height of 1124 feet above the sea; Hanover, New Hampshire,—on the east bank of the river, in lat. 43° 42′ N., long. 72° 17′ W., at a height of 530 feet above the sea; and at Amherst, Massachusetts, in lat. 42° 22′ N., long. 72° 34′ W., at a height of 267 feet above the sea; the first, from tables kept by Dr. H. Cutting of Lunenburg; the second, from the Dartmouth Observatory at Hanover (received from Prof. R. Fletcher); and the third, from the tables of Prof. E. S. Snell. The table shows that the floods are not the immediate effect of great rains, and this is plain from mere inspection.* So in the Glacial era, the loss of water by soil-absorption was at its minimum, by growing vegetation almost null, and by chemical processes of oxidation and hydration† very small, while ice to melt and melting and frozen ground to flow over were essentially indefinite in extent.

An allowance, therefore, for the loss from evaporation and other causes, of 20 to 25 per cent. during the glacier-melting, cannot be far from right. Taking the mean of these numbers, 22½ per cent, the amount for the whole precipitation, 21·8 cubic miles, becomes 16·9 cubic miles as the part contributed to the discharge of the flooded river; and this in the state of ice is 18·4 cubic miles. Consequently all the discharge but this portion would have been derived from the wasting glacier—which makes the waste per year (p. 367) 460·1 cubic miles if the velocity of the river were four miles an hour, and 340·6, if three miles, the former equivalent to about 1·26 cubic miles per day, and the latter to 0·933.

(6.) *Disappearance of the Ice.*—If the loss of ice by melting were 460·1 cubic miles per year, and this amount continued to be the loss uninterruptedly, 8,215 cubic miles of ice would have been carried off in about 18 years; and if the annual

* One marked exception occurred in August, 1856, when the waters of the river reached a height of 23·33 feet at Hartford, or but 25 per cent short of the highest on record (that of May, 1854, when the height was 29·83 feet). But the precipitation at that time was enormous, having been in that August 12·132 inches at Amherst (Snell), and 11·68 inches at Wallingford, Connecticut (B. F. Harrison, in this Journ., xxi, 497, 1881).

† The loss by hydration here alluded to is in part that used in making the clay of the glacier discharge which is abundant in Greenland as well as in the products—bowlder clay—of the Glacial era. Such clay has been made by the decomposition of the feldspar which the glacier-movements grind up, and when pure contains 13 per cent or so of water. The decomposition is a remarkable fact; but it is possible that the decomposition of the algæ of the glacier may have made carbonic acid to promote it

	Discharge in millions of cubic feet.	Monthly precipitation.				Discharge in millions of cubic feet.	Monthly precipitation.		
		Lunenburg.	Hanover.	Amherst.			Lunenburg.	Hanover.	Amherst.
1872.					1873.				
Jan.	29,288	1·95	2·88	1·51	Jan.	64,430	3·85	3·05	3·01
Feb.	18,849	3·05	2·80	1·89	Feb.	45,123	3·35	1·75	3·17
March	22,437	2·70	3·24	2·87	March	43,316	4·50	3·54	3·18
April	130,966	2·07	0·40	2·20	April	181,780	2·65	1·32	1·74
May	82,164	8·20	3·42	3·11	May	138,720	2·64	1·21	3·91
June	63,696	7·34	4·34	3·25	June	26,400	2·00	1·74	1·59
July	26,918	7·25	5·64	7·07	July	18,982	3·95	5·91	2·93
Aug.	59,996	12·79	7·35	5·28	Aug.	17,270	2·50	1·52	3·47
Sept.	53,388	3·48	2·62	6·20	Sept.	17,718	4·75	3·83	4·77
Oct.	41,923	2·47	1·57	3·64	Oct.	66,780	5·45	5·57	6·36
Nov.	62,897	5·05	0·75	4·48	Nov.	39,915	2·22	2·38	3·51
Dec.	45,548	5·00	2·27	2·69	Dec.	66,726	2·65	1·65	3·31
Total	638,070	61·35	37·28	44·19	Total	727,160	40·51	33·47	40·95
1874.					1875.				
Jan.	135,491	3·70	2·90	5·46	Jan.	17,079	2·60	3·92	2·90
Feb.	96,674	1·80	1·81	2·18	Feb.	27,023	4·92	1·20	3·62
March	71,721	2·25	0·68	1·35	March	49,032	3·05	2·55	4·20
April	62,031	4·05	3·40	6·03	April	146,049	2·85	1·92	3·33
May	139,213	2·95	3·26	5·22	May	111,437	3·73	3·94	2·19
June	74,110	7·06	3·44	5·06	June	35,607	5·70	4·98	2·89
July	55,018	4·98	5·07	1·16	July	22,991	2·55	2·70	8·15
Aug.	28,293	4·38	2·01	2·69	Aug.	31,971	3·40	4·07	6·16
Sept.	17,412	1·35	3·92	1·82	Sept.	17,468	4·35	1·94	4·65
Oct.	19,310	1·15	1·30	0·85	Oct.	27,387	5·26	3·94	3·89
Nov.	15,865	2·71	1·92	3·54	Nov.	41,022	2·92	1·63	3·97
Dec.	17,965	3·07	1·08	1·17	Dec.	43,583	1·40	0·78	1·03
Total	733,103	39·45	30·78	36·53	Total	570,649	43·73	33·57	46·98
1876.					1877.				
Jan.	79,956	3·55	1·72	2·30	Jan.	17,500	2·15	2·70	2·52
Feb.	64,400	3·60	3·59	5·53	Feb.	18,491	0·65	0·00	0·36
March	93,866	3·02	3·50	7·10	March	93,253	6·40	2·57	6·97
April	160,756	2·75	0·52	3·10	April	110,247	2·35	1·97	2·45
May	155,521	4·70	1·32	3·96	May	45,374	1·05	1·03	1·93
June	41,008	7·05	3·46	3·87	June	20,907	3·00	4·07	4·59
July	22,016	5·25	0·00	4·84	July	25,475	4·22	8·48	6·47
Aug.	16,674	1·25	0·42	0·27	Aug.	22,946	5·95	4·01	2·79
Sept.	17,186	5·90	4·58	3·71	Sept.	18,089	2·05	0·91	0·91
Oct.	16,930	1·60	0·53	1·12	Oct.	31,772	4·70	4·67	6·98
Nov.	20,822	1·67	2·13	2·49	Nov.	75,825	3·65	3·81	5·44
Dec.	17,156	2·81	1·30	3·22	Dec.	46,382	1·87	0·96	1·02
Total	706,291	43·15	26·07	41·51	Total	526,261	38·04	35·18	42·43

At Norwich, on the west side of the Connecticut, opposite Hanover, the precipitation in 1872 was 41 inches, in 1873, 36·57, in 1874, 35·32; greater, in each case, than at Hanover. Schott makes the annual *mean* at Hanover 40·66.

The number of inches of snow in the above years at Lunenburg and Hanover was as follows:

Year.	Lunenburg.	Hanover.	Year.	Lunenburg.	Hanover.
1872	139·50	28·75	1875	122·45	106·73
1873	136·20	100·00	1876	90·85	113·00
1874	118·85	77·70	1877	42·75	32·00

loss were 340·6 cubic miles, the same work would have taken about 24 years.

8,215 cubic miles of ice are equal to the part of the glacier estimated to have occupied the drainage-area of the Connecticut at the time of maximum ice.

Supposing the above numbers approximately correct, we are still far from a knowledge of the time taken during highest flood for the disappearance of the ice from the valley. For in order to reach a conclusion it is necessary to know *also*,

(1.) The approximate amount of ice that was still in the valley when the epoch of maximum flood was reached, the estimate made being the amount at the time of maximum ice.

(2.) Whether the southward movement of the great northern glacier still continued, and was adding to the amount of ice.

(3.) What was the amount of ice contributed at that time by local glaciers within, or on the borders of, the drainage-area, which glaciers used some of the precipitation to make ice for melting.

(4.) Whether the melting, instead of continuing on uniformly, had its years or periods of interruption.

(5.) Whether the time of maximum flood was not quickly passed, even in one, two or three years, so that the discharge of the river was at its highest stage only for a very short time and rapidly declined to some limit, lessening thereby, both the rate of flow and the amount of water.

With doubts on points so important, this time-question must be set down as of impossible solution.

But while a definite answer is not to be expected, we may see reason for the following general inferences.

a. At the time of maximum flood the ice was not lying along the center of the valley producing the river by its gradual melting, and retreating northward as the river elongated in that direction.

The amount of water flowing off with a velocity of three or four or more miles an hour, making the great flood, was too vast to have been generated from a retreating body of ice in the valley.

b. If, as Greenland facts authorize us to believe, sub-glacial rivers of large size and energy were a universal feature of the Glacial era, these streams must have entered on a career of real progress when melting began in earnest. As they enlarged, the icy tunnels they had hitherto occupied would have become widened, and the sub-glacial chambers have extended themselves in all directions, undermining the heavy glacier. And as rapidly as this removal below went on, the deposition of the materials of the ground moraine—the stones, gravel, earth and clay—long before initiated—would have gone forward, covering

with till the glacier-buried land. But, subsequently, when the rising streams had volume enough to make the lower range of terraces, along the valleys, the roofs of the tunnels were probably, for the most part, gone. The ice still lay over the land, covering deeply the hills and mountains, but the wide channelways were open to the day. Evidence of this is afforded by the fact that these lower terraces, like the higher, are free, with rare exceptions, from deposits or droppings of till or of bowlders, such as would have come from an overhanging glacier. But outside of the terrace plains, up the hill slopes wherever the ice still remained in force, the till may have continued to fall, adding later to earlier till. Other evidence that the streams, as the floods rose and terracing went forward, were free from ice overhead is afforded by the Lake Champlain and St. Lawrence valleys. The shell-bearing sea-beach deposits at Montreal and on Lake Champlain could hardly have been formed from a thriving growth of mollusks and other marine species while the glacier lay over the whole region to the Gulf, a distance from Montreal of 500 miles. Whales (*Beluga Vermontana*, resembling much *B. leucas* Gray), and seals, inhabitants of the bays of Arctic coasts, would never have made their way beneath such a cover of ice to Lake Champlain, a region also under the ice. If then the St. Lawrence valley for more than 500 miles and the Lake Champlain region were free of ice, this may also have been true of the larger valleys of New England and the west.

c. It follows from the existence of a cut across the glacier along the St. Lawrence valley, from Lake Ontario to the Ocean, over 500 miles from east to west, and north of all New England, that at the time of highest flood New England was not receiving additions to its ice through the southward movement of the great northern glacier.

d. The Connecticut valley, at the time of maximum flood, derived its waters—apart from the portion supplied by precipitation—from the ice of the bounding slopes of the valley and of the wide tributary region. Consequently, the melting surfaces up and down the borders of the valley and over the slopes east and west to the limits of the tributaries would have been of almost indefinite extent, and the ice thus melted might have reached the amount deduced above—a cubic mile per day.*

* It will be observed that such conditions were well fitted, especially toward the mountains or in the region of the upper sub-glacial portions of the tributary streams, to produce and set afloat masses of ice laden with till, to float down a tributary to the Connecticut—a kind of work that must have begun early in the era of melting. Reaching the wide borders or flood-grounds of this river, they would, for the most part, have been pretty sure to have become stranded above and below the mouth of the tributary, owing to eddies and shallows; and there, as they melted, would have dropped their stones and earth, and thus have helped to make the coarse gravel and cobble-stone beds which, in

e. The length of time during which the waters stood at maximum height was probably less than five years. This accords with the following facts: that the terraces marking this upper level have much less extent than those of lower levels; that they are confined more narrowly to the vicinity of the mouths of the tributaries—the transporters and distributers of terrace-material; and that they are absent altogether from some long portions of the valley, except quite close to or within the mouths of tributary streams. As already remarked, the height of the flood may have exceeded, for a short time, the deduced heights by 10 or 20 feet; and a wide range of evidence of this may yet be made out.

f. The approximate length of the era occupied by the rise and fall of the flood is not a question within the range of this paper, and does not appear to admit of determination by any of the facts considered.

Art. XXXIX.—*On Brazilian specimens of Martite;* by Orville A. Derby.

The opinion has lately been advanced (M. Gorceix, Comptes Rendus de l'Acad. des Sci., No. 7, 1880; Annals da Escola de Minas de Ouro Breto, No. 1), that the octahedral crystals of oligiste, so common in the metamorphic schists of Minas Geraes and known by the name of martite, are due to the transformation of pyrites. That this is true of some of the crystals, is beyond a doubt, but a recent examination of fine collections from typical localities indicates that a large portion should rather be considered as produced by the alteration of magnetite.

In a lot of 308 crystals ranging from 2 to 10^{mm} in diameter, collected by myself from a single locality near the village of Itambé, from a partially decomposed quartzose micaceous schist, 116 were attracted and for the most part freely lifted between the poles of a small horse-shoe magnet, and of these 57 were freely attracted by a much stronger bar magnet, only a few being lifted freely. 192 were not attracted by the horse-shoe magnet, and 251 showed the same indifference to the bar magnet.

many places to the north, compose the topmost portion of the higher terraces (indexes of the so-called "Kames.") The stones of such ice-floes would have been largely from *northern* sources, whatever the direction of the stream contributing them, as explained on page 89.

The liability of floating masses to strand, and to drift up stream as well as down, in consequence of eddies along the sides of a river, is illustrated in an instructive way on the Connecticut, in early summer, by the great crowd (sometimes millions together), of logs (tree-trunks) that float down it to lumber-yards in Massachusetts and farther south. Were it not for a large party of hands to look out for the logs and keep them moving, they would be generally ashore before going far on their course. The bends in the stream add much to the difficulties.

A specimen which was lifted freely by both magnets gave a black strongly magnetic powder, reacting with both ferri- and ferro-cyanite as well as with sulphcyanite of potassium. Another specimen not attracted by either magnet, gave a red powder which was feebly attracted between the poles of the horse-shoe but was not influenced by the bar magnet. This gave a characteristic reaction with sulph- and ferro-cyanite of potassium, but with the ferricyanite only gave an almost imperceptible blue precipitate which was immediately lost in the coloration due to the great excess of peroxide.

A specimen extracted from a greenish micaceous schist from Inficionado (locality from which martite was first described by Spix and Martius) apparently identical with the Itambé rock, but not decomposed, was strongly attracted by both magnets and gave a black strongly magnetic powder reacting for both per- and protoxide of iron. From a similar rock from Serro, partially decomposed, two specimens were extracted, one with a brilliant surface, the other somewhat dulled. Both were magnetic but in different degrees and both gave the reactions for the two oxides, but the powder of the first was black and of the second red. In another specimen from near Serro, small splendent, strongly magnetic crystals, giving a black powder, were embedded in compact hematite. In another small lot of brilliant crystals, all were so strongly magnetic as to form themselves in strings of four or five on both magnets.

In these experiments all possible gradations as regards magnetism and composition between typical magnetite and oligiste, were found. Specimens from the surface, or from much decomposed rock, will naturally be of pure oligiste, but present no external evidence of the change from magnetite unless it be an almost imperceptible dulling of the surface and a slight coppery luster.

Art. XL.—*A method for determining the flexure of a Telescope Tube for all positions of the Instrument;* by J. M. Schaeberle.

In all observations with the meridian circle only the maximum *astronomical* flexure of the telescope tube is determined directly from observations, two horizontal collimators being used for this purpose. This maximum flexure is then assumed to vary as the cosine of the altitude. I propose in this paper to give a very simple method by means of which the accuracy of this law can be tested directly for all positions of the tube, nothing but a small plane mirror, silvered by Draper's process, being required for this purpose. To this mirror is cemented a circular ring of cardboard of just sufficient thickness to prevent

the mirror from touching the object-glass of the telescope to which it is cemented with a solution of gum arabic. The centering is quickly done by shifting the mirror upon the spherical surface of the lens until the reflected image of the horizontal wire is nearly in coincidence with the wire itself.

In experimenting I have used a piece of plate glass: to test the surface of the same before silvering, the image of a distant brick wall, reflected obliquely from the glass surface, was examined with the aid of an excellent $2\frac{1}{2}$ inch achromatic; from a number of pieces one was selected which gave a sharp image of both the vertical and horizontal joints for the same focus. A beautifully sharp and fine image of the wires will be given by such a mirror (silvered on the side toward the object-glass) although less than two inches in diameter.*

Let m_1 be the reading when the micrometer wire is in coincidence with the reflected image of the fixed horizontal wire, the telescope being pointed to the zenith, and let m be the reading for any other pointing. Let x and y be respectively the deflections of the object- and eye-ends of the tube from the positions these ends would have if there were no flexure.

L= focal length of objective.

l= distance of the object-glass from the line about which the flexure causes it to revolve. Placing the sines and tangents of very small angles equal to their arcs, the linear distance of the fixed wire from its reflected image, can be expressed by a very simple equation. For we have,†

$$\frac{2}{\sin 1''}\left(\frac{x}{l}-\frac{x-y}{\mathrm{L}}\right)=\frac{m-m_1}{\mathrm{L}\sin 1''}, \quad \text{therefore}$$

$$x\left(\frac{\mathrm{L}}{l}-1\right)+y=\frac{m-m_1}{2}.$$

Letting $\left(\frac{\mathrm{L}}{l}-1\right)=c$ and $\frac{m-m_1}{2}=\mathrm{F}$, we can write

$$\begin{aligned} cx\ +y\ &=\mathrm{F}\\ cx'+y'&=\mathrm{F}'\\ cx''+y''&=\mathrm{F}'',\\ &\text{etc., etc.}\end{aligned}$$

If f_0 represents the maximum *astronomical* flexure determined by means of two horizontal collimators, we have

* The focal length of the objective used is eight feet, and the wires made visible in precisely the same way as in taking nadir observations.

† The flexure really gives the tube a curved outline. In assuming that the change in the inclination of the mirror (due to flexure) is equal to $\frac{f}{l\sin 1''}$ (where l can usually be taken equal to the distance of the objective from the nearest face of the cube, to which the tube is bolted) only very small terms are omitted which can generally be neglected as inappreciable.

$$f_0 = x_0 - y_0$$
$$F_0 = cx_0 + y_0$$

hence we obtain

$$x_0 = \frac{f_0 + F_0}{c+1} \qquad y_0 = \frac{F_0 - cf_0}{c+1}.$$

Representing the zenith distance of the pointing by z we should have

$$(cx_0 + y_0) \sin z = cx + y = F$$
$$(cx_0 + y_0) \sin z' = cx' + y' = F',$$
etc., etc.

provided the law, that the flexure varies as the cosine of the altitude, is correct.

If the measured values F, F′, etc., are not satisfied by the above equations, the residuals will furnish data for obtaining the form of the function which, when substituted in the place of *sin z*, will best represent the observed readings. Any sudden *apparent* change in the flexure, as for instance the shifting of the object-glass in its cell, could be observed directly by keeping the eye at the instrument while it is being revolved. In some cases it might be well to fasten the mirror to the cell instead of to the objective. After the flexure has been determined, a thin strip of metal, the weight of which is exactly equal to the weight of the mirror, can be wound around the object end of the tube.

ART. XLI.—*On the dykes of Micaceous Diabase penetrating the bed of Zinc Ore at Franklin Furnace, Sussex County, New Jersey;* by BEN. K. EMERSON.

THE great open working at the Taylor mine in the "Buckwheat Field," at Franklin Furnace, is carried forward for a long distance with a width of perhaps fifty feet and a depth of ninety feet. As the limestone bed dips 90°, the walls are vertical, and as the ore body in this limestone bed has a steep pitch to the north, the mine is at its north end no longer worked out today, and as if planned specially for the convenience of the miners, a great vertical dyke 20–22 feet in width cuts the limestone and the ore bed at this point, and standing vertically stretches at right angles across the mine like the partition wall of a burned building. Seventy feet above the floor of the mine and again at the bottom passages have been cut through the dyke to get at the ore behind. From a point near the southern foot of the dyke, smaller dykes run up to the surface dipping 50° S., widening and narrowing and sending off small branches. These smaller dykes do not exceed two feet in thickness. Twenty feet farther south another dyke more inter-

rupted, and never more than six inches thick, runs nearly to the surface. This is the appearance of the dykes in the west wall. In the east, the dyke last mentioned is thicker and continuous from top to bottom, and the two small dykes which start on the west from the foot of the main one are widely separated. The effect of these dykes upon the zinc ores is remarkable. Large portions of the eruptive rock have exactly the appearance of an amygdaloid, but the amygdules are spheres of green willemite melted out of the vein, and such drops, together with franklinite could be found, though more rarely, in the coarsest rock, from the center of the main dyke. The smaller branches running down to a width of a quarter of an inch, and penetrating the richest portion of the ore—the "green silicate"—are changed to a depth of a quarter of an inch or more into a red jaspery mass, which retains its thickness as the dyke thins, so that dykes less than an inch in thickness are made up wholly of the brick red aphanitic material. In the thicker veins from which these filaments spring, the rock as a whole grows aphanitic toward the contact, while the scales of mica are even larger and are arranged parallel to the contact plane. The rock has the appearance of a very micaceous diorite; is brownish gray in the coarser varieties to nearly black in the finer, and varies from aphanitic to a coarser kind where the red mica is abundantly visible to the eye, and more rarely small black augites appear. It is of high specific gravity and effervesces abundantly with acid.

Microscopically it resembles closely the finer grained, dark colored elæolite rock from Beemersville which there seems to be an offshoot from the great main dyke, and it was for this reason as well as to observe the effect of the large admixture of the zinc silicate, investigated with the microscope. The resemblance was not sufficiently close to make it probable that the dykes of the two localities are of the same age and origin.

Under the microscope the foreign constituents, franklinite, zincite, willemite and calcite, are present in large quantity; the zincite easily mistaken for franklinite from its opacity but showing on the thinnest edges a deep blood red. The willemite is especially abundant, both in round drops apparently melted, —green, semi-transparent, fissured by many cracks, and showing feeble polarization,—and in broken crystals and large cleavage pieces It resembles olivine in many ways, having a strongly marked but irregular rectangular cleavage and a very rough surface in thin sections, but it polarizes feebly and without bright colors. In this respect it differs from the normal willemite, which was sliced for comparison, from an inch outside of one of the small dykes, which resembles and rivals olivine in the brilliancy of its colors in polarized light.

The normal constituents of the rock are labradorite, augite, biotite, apatite, and probably magnetite, though one cannot well distinguish the latter ingredient from the franklinite. The colorless background in which the other constituents appear polarizes in large irregular patches, and for the most part shows neither cleavage nor any other characteristic by which it can be determined in its present decomposed state. A small portion, and this was increased by treatment of the slide with acid, shows multiple twinning with extinction at 10° on either side of the twinning plane, which would indicate labradorite, and it often combines with this a second twinning at right angles to the first. Another portion shot through with brightly polarizing scales of muscovite resembles a decomposing elæolite. Experiments with regard to gelatinization gave uncertain results, from the presence of so much zinc silicate, but some portions which did not seem to be willemite were removed by acid.

The abundant scales of biotite are with great frequency pierced by unusually large regular prisms of apatite, and decomposition has attacked some crystals at the edge, and following in on certain layers has changed them into an aggregate of colorless scales apparently of silica. The augite is of very light brown color, and appears in unusually long flat blades from the great development of the orthopinacoid. It is without absorption and extinguishes the light at 37° to the vertical axis. One finds in addition scattered crystals of much larger size (·2 mm.) which have the stout form and the color of common volcanic augite, and in several instances enclose large fragments of willemite and franklinite, or willemite and pyrite, and are also surrounded by a greenish zone of equable width which shows aggregate polarization, and consists of willemite and calcite.

In other varieties of finer grain, the elongated crystals of augite, and plates of red mica similar in shape and size to these, are more abundant and fill the field in reticulate arrangement, as do the feldspar needles in a common diabase. Moreover a gray or greenish gray semi-opaque substance, made up of scales and irregularly rounded particles, is gathered in great quantity around these crystals so that they are often almost wholly concealed thereby, and look like caddis worms in their cases. This is the seat of very abundant effervescence when the slide is treated with acid, but is only partly removed.

The feldspathic constituent appears here also as a colorless background, but more sparingly, and it is even more decomposed than in the coarser rock. It differs from this only in enclosing in abundance straight acicular microlites which are abundant also in the elongate augite crystals.

The finest grained black rock three inches from the contact

in the main dyke showed under the microscope a uniform gray ground difficult of resolution and resembling that of a phonolite, and regularly mottled by abundant small rounded opaque spots.

When examined with a power of 600, it is found to show small portions of a colorless isotropic glass which is crowded with minute particles apparently spherical scattered either singly or joined three or more together into moniliform rods, or, finally, densely agglomerated into the opaque spheres with which the ground is mottled. These products of the devitrification of the glass-base bear close resemblance respectively to the globulites, margarites and cumulites of Vogelsang, except that they do certainly polarize light.

On this background appear (*a*) large, often well-formed crystals of franklinite or magnetite, (*b*) very abundant clear hexagonal cross-sections which appear to be apatite, and others larger and clouded with the included microlites which may be nephelite, (*c*) small very regular sections of pale brown augite sometimes beautifully twinned, and (*d*) rare scales and needles of biotite. The augite crystals are often in flat blades, from the large development of the orthopinacoid, and extended in the direction of the vertical axis into long needles with well developed basal cleavage, which resemble somewhat needles of fibrolite, but extinguish the light at an angle of 37° with the vertical axis.

The larger crystalline constituents described are here scattered at a distance from each other in the semi-opaque ground mass and show a very distinct fluidal structure.

Finally, in the jasper-like material of the narrow red filaments, the ground is in thin section deep red and the material resembles the basic volcanic glasses in the difficulty of getting a transparent slide. The ground has however undergone complete or almost complete devitrification and the opacity is caused by the close aggregation of minute grains resembling those of the preceding variety but redder and even more minute than they, which gave when the light could be driven through the thinnest portion of the slide bright aggregate polarization

Quite large pieces of included willemite and zincite occur abundantly. The zincite is of so deep color that by ordinary light most of the pieces are quite opaque and only here and there a blood red light penetrates a small portion of the surface. Curiously with crossed Nicols these masses of zincite glow out like carbuncles and the bright red of the background quite pales beside it. It is at the same time quite apolar.

A multitude of sharp hexagonal apatite cross-sections let the light through the dark ground, and the same pale brown augite and red mica appear as in the other varieties,

Art. XLII.—*On the Occurrence of Smaltite in Colorado;* by Malvern W. Iles.

A vein of cobalt-bearing minerals, containing smaltite in predominant quantities, has recently been discovered near Gothic, Gunnison County, Colorado.

The vein is strong and well defined, indeed projects from a granitic formation in several places. This property, owned by the Sterling Mining Co., has as yet received but little development, but sufficient to lead one to believe it will be a commercial source for cobalt.

The vein matter contains much crystallized calcite, in which are irregularly distributed smaltite and erythrite. There is occasionally noticed a small amount of iron pyrites, and also very beautiful spongy leaflets of native silver. The vein is particularly free from siliceous matter, and up to the time of writing, we have been unable to detect any associated nickel minerals.

A sample of smaltite obtained from the surface croppings yielded the following results:

Co	11·59
Fe	11·99
As	63·82
SiO_2	2·60
Pb	2·05
S	1·55
Bi	1·13
Cu	0·16
Ni	trace
Ag	"
	98·89

A purer sample yielded 15 per cent. cobalt.

The Gem, and other mines, near Silver Cliff, Colorado, contain a number of nickeliferous minerals, and a small amount of cobalt.

The writer has recently detected a small amount of nickel and a trace of cobalt in an iron pyrites near Granite, Colorado; the latter mineral bears a striking resemblance to the nickeliferous iron pyrites found at Anthony's Nose on the Hudson River.

Chemist, Grant Smelting Co., Leadville, Colorado.

Art. XLIII.—*On the occurrence of Vanadium in the Leadville Ores;* by Malvern W. Iles.

At the Evening Star and Ætna Mines, I have detected a vanadium mineral, occurring in a pocket surrounded by a siliceous gangue, and also in a well-defined seam. In the Evening Star mine, the vanadium compound is associated with the so-called "hard carbonate of lead," and is found as an incrustation upon a dark chocolate-colored siliceous gangue, which gangue is in turn deposited upon nearly pure white quartz. The mineral in question has various shades of color, from red to yellow, and may be described as orange-red, reddish-yellow and lemon-yellow. Both the red and yellow specimens give a deep green solution when treated with hydrochloric acid, and not unfrequently the chocolate-colored mineral gives a marked amount of vanadic acid.

Prof. Silliman has called attention to the fact that a chocolate-colored mineral, found associated with vanadinite, also yields a perceptible amount of vanadium.* The reagents, upon which most reliance was placed to detect the presence of vanadium in the numerous specimens at my disposal, were hydrogen peroxide and potassium ferrocyanide; and the property vanadium compounds have of giving a green solution with hydrochloric acid was made use of. Portions of the brilliant colored incrustation were detached from several specimens, and submitted to a chemical examination; the results make it probable that the mineral is dechenite. The analysis is as follows:

SiO_2	36·86
PbO	38·51
ZnO	9·07
V_2O_5	9·14
Fe_2O_3	2·59
H_2O	2·41
CO_2	0·48
	99·06

In the estimation of vanadic oxide we used the method of precipitating the vanadium as a basic lead vanadate, and subsequently decomposing this salt by means of dilute sulphuric acid; the concentrated filtrate, after using the well-known precautions to ensure removal of all traces of lead, was transferred to a platinum crucible, the sulphuric acid cautiously expelled, and then strong heat was applied with a blast lamp until complete fusion of the vanadic oxide.

* This Journal, III. xxii. 200, 1881; Engineering and Mining Journal, Sept. 3d 1881; Transactions American Institute of Mining Engineers.

Art. XLIV. — *On Certain conditions attending the Geological Descent of some North American types of Fresh-water gill-bearing Mollusks*; by C. A. White.

[Extracted in advance from the Annual Report of the U. S. Geological Survey for 1882, by permission of the Director.]

The following remarks are extracted from an article entitled a Review of the non-marine Fossil Mollusca of North America. They are intended to apply especially to the fresh-water Mollusca of the Laramie and Eocene deposits of Western North America, and their descendants now living in the Mississippi drainage-system, and are offered as an explanation of the manner in which that system became stocked with its present characteristic molluscan fauna, and doubtless to a large extent, with its ichthyic fauna also.

When we attempt to trace the probable lines of succession or descent of the various types of Mollusca that now exist, the difficulty seems especially great, when casually considered, in the case of the fresh-water gill-bearing Mollusca.

The prevalence of the sea has always been practically universal: and the various movements which the earth's crust has undergone since life began in the sea, while they have repeatedly disturbed or destroyed the habitats of its molluscan denizens in certain localities, and many of the lines of genetic succession of types that had from time to time become established have been broken, there has evidently never been anything like such a general destruction of life in the sea as would either break or materially interfere with the greater part of the principal lines of such succession. In short, the marine field for the development and perpetuity of molluscan life has been ample and unbroken from the beginning to the present time, and we are at no loss to understand how continuous lines of genetic succession of its denizens may have extended down through all the geological ages, modified it is true, by immediately environing and cosmical causes, but still unbroken. We may at least conclude that if every molluscan species that now exists in the sea has not been lineally derived from the earliest molluscan forms that have existed in it, there have been no such changes of its physical conditions as would preclude such a possibility.

When we come to the study of the fossil pulmonate Mollusca, especially the land-shells, we have also little or no difficulty in understanding how it has been possible for continuous lines of existence of these mollusks to be preserved through successive geological periods upon any continental area, such for example as North America, notwithstanding the numerous and

great physical changes that have taken place within its area during those periods. Being air-breathers, nothing has apparently occurred to prevent their safe migration to other ground whenever that which they may have at any time occupied became uncongenial by reason of physical changes, because as a rule, those changes were effected so slowly that a continuity of congenial habitat for such mollusks was not necessarily broken. They were thus apparently as capable of preserving a continuous existence through successive geological periods as the marine mollusca were.

But, as before intimated, when we come to the study of the fossil shells of the fresh-water gill-bearing mollusca, which in their living state must necessarily have been confined to fluviatile and lacustrine waters, it is not easy to understand, without a special explanation, how continuous genetic lines could have been preserved (as we find they were preserved even down to the present time) through a succession of geological periods, during which the great lakes of the Laramie and succeeding Tertiary periods, as we know, and all the rivers which flowed into and from them, as is generally but erroneously believed, have been successively obliterated.* Rivers are separated from each other by intervening land, and, running to the sea, their mouths are separated by marine waters, neither of which barriers are fresh-water gill-bearing mollusks capable of passing. But if it can be shown that throughout those geological periods and down to the present time there has been direct continuity of fresh water by means of lakes or rivers, or both, the case is plain enough. Indeed, as precarious as the existence of continuous life of that kind may seem to have been, under the circumstances of such vast physical changes as are known to have occurred, we are forced to conclude that it is in this direction that we must seek for an explanation of the manner in which were preserved the fresh-water molluscan types that have been found in the various groups of North American Mesozoic and Cenozoic strata, and that we also find among living mollusca. That is, they have been preserved through a continuity of habitat in the congenial fresh waters of lakes and rivers, flourishing in the lakes, when they existed, as well as in the rivers, and escaping by the streams which were the former

* It may be suggested that the distribution of these forms from one river or river system to another, may have taken place by the transportation of the mollusks or their eggs by aquatic birds. While such transportation is admitted to have been possible in some cases, it cannot be admitted as a probable cause of any considerable part of the distribution that must have occurred during the several geological epochs in which the molluscan types referred to are known to have existed. Notwithstanding the annual migration of myriads of aquatic birds between the northern and southern portions of North America ever since it has been a continent, the fresh-water molluscan faunæ of those regions, respectively, are still distinct.

outlets and inlets of the lakes, but which continued to flow after the obliteration of the latter, as rivers or tributaries of river systems.

Lakes are only parts of unfinished river systems which disappear when the system is finished by the erosion of its channel to a nearly uniform slope. A lake consequently contains essentially the same aquatic fauna that the fluviatile portion of the system does in case the water of the lake is wholly fresh; or a modification of that fauna if the water is more or less saline. The great lakes of the Tertiary and Laramie periods have successively become obliterated; but we may reasonably conclude that at least a part of the river channels of to-day have existed as such from former geological times; that the greater part of them were established in epochs anterior to our own, and that those of some of the tributaries of the present Mississippi River system are identical, at least in part, with former outlets or inlets, or both, of the great ancient lakes which have been referred to. Consequently we may reasonably conclude also that the molluscan fauna of the Mississippi River system is lineally descended from the faunæ of those ancient lakes, and the river systems of which they constituted lacustrine portions. This view is confirmed by the identity of the living with the fossil molluscan types which have been found so abundantly in those Laramie and Eocene deposits.

In these remarks the ancient Laramie sea is included under the term "lacustrine," the term "sea" being used simply to indicate that its waters were saline and not fresh; just as the Black and Caspian are called seas instead of lakes, and for the same reason. It may seem to be the use of a misnomer to speak of the Laramie sea as a part of a river system, because it was so immensely large, and the continental area which was drained into it was proportionally so small, but if these views concerning the conditions which then existed are correct, that sea, with its tributaries and outlet, differed only in degree and not in kind, from any river system which has a lake of any size in its principal course. The waters of that sea having been saline, the Laramie hydrographic system more nearly resembled that of the Black Sea than any other now existing that is equally well known; and, although that ancient sea has long since disappeared from the face of the earth, its "Hellespont" still flows as a part of the Missouri River, or of some one of its tributaries.

Rivers have of course existed ever since a sufficient extent of continental surface was raised above the sea to accumulate the waters that fell from the clouds; and in view of the mighty changes that have taken place during the progressive

growth of the North American continent, especially the elevation of its great mountain systems and plateaus, it would be natural to suppose that the earliest rivers at least have been obliterated. Some have no doubt been obliterated, but contrary to what has been the general belief, the recent labors of Powell, Dutton and others have shown that the rivers of North America have been among the most persistent of its physical features; that many of them are older than the mountain ranges of the regions which the rivers traverse, and that they have not yielded their "right of way" when the mountain ranges and plateaus were raised, but continued during and after that elevation to run in essentially the same lines which they had chosen when the region they traversed was a plain instead of a mountainous one. That ancient river systems have been in some and perhaps many instances, to a greater or less extent divided, as a consequence of unequal continental elevation, or from other causes, is quite certain; and it was doubtless in part by this means that the dispersion of freshwater mollusca into different river systems has been effected. That some formerly existing rivers have been obliterated and their molluscan faunæ destroyed is doubtless also true, but these facts do not necessarily affect the correctness of the view concerning the general persistent integrity of rivers and river systems which has been referred to.*

The coalescence of separate minor drainage systems by the confluence of their lower portions into a common channel during the progressive elevation of the continent has also been an important means of the dispersion of fluviatile Mollusca. By such coalescence, what were once separate rivers or minor drainage systems became parts of larger ones; as, for example, the union of the separate peripheral members of the great Mississippi River system, which now forms a common drainage for the principal part of the continent. The Ohio and Upper Mississippi, the two most ancient portions of the present great system, were once separate rivers, emptying into a northern extension of the Great Gulf; and it is practically certain that neither of them received that portion of the molluscan fauna, which now so strongly characterizes them, until after the confluence with them of the western portions of the

* The discovery of so few traces of fluviatile deposits as have been made among the strata of the earth is probably due to the persistent adherence of rivers to their ancient channels. When land upon which rivers have formerly run has subsided beneath the level of the sea, the fluviatile deposits were doubtless destroyed by the encroaching marine waters. If the land continued to rise, as has been so generally the case in the gradual production of the North American continent, the earlier river deposits were swept away in later times by their own waters, as their valleys were broadened and deepened. It is therefore, as a rule, only in the deposits of lacustrine portions of ancient river systems that their faunæ have been preserved.

present great river system which brought that fauna from its ancient home in the western part of the continent.

Rivers having been thus persistent, and the manner in which confluence of the waters of many of them has been effected being understood, it is no more remarkable that the types of fresh-water gill-bearing mollusca have come down to us practically unchanged, than it is that marine and land mollusks have reached us bearing the imprint of their really ancient, but what we have been accustomed to call, modern types.

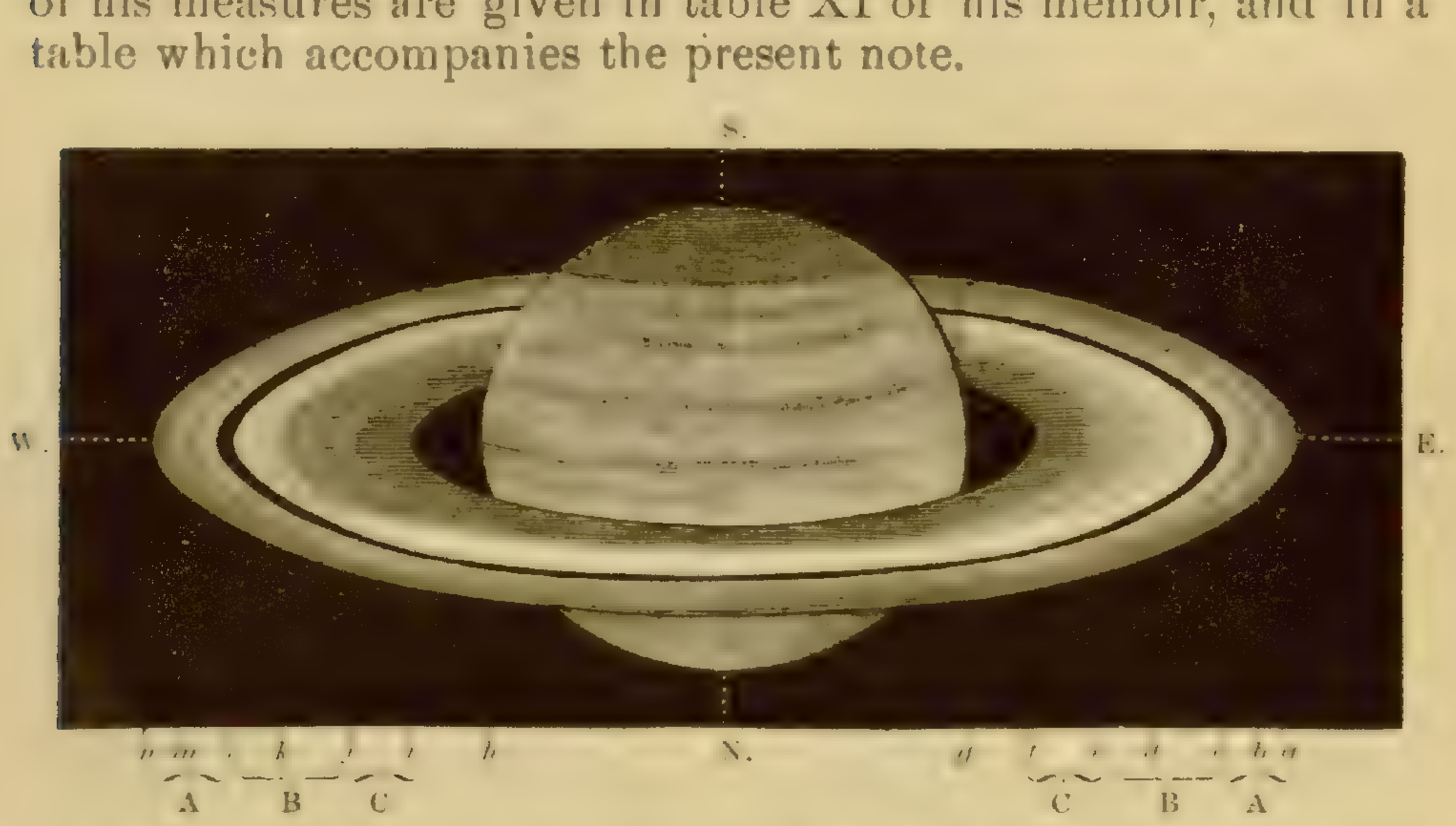
Not only have the molluscan denizens of the great Mississippi drainage system descended to their present habitat in the manner suggested; but there is no reason to doubt that a large part of the fishes of that system descended in the same manner, and in company with them. This is thought to be especially true of the characteristic Ganoids of that system. The progenitors of many of the fresh-water fishes may have ascended from the sea by the mouths of the rivers which have since coalesced to form that great river system: but it is believed that all did not do so.

Both molluscan and ichthyic life doubtless began in the sea: and it seems at least probable that the freshwater denizens of a large part of both these classes became such by compulsion rather than from choice. That is, their original progenitors were probably land-locked by the gradually and unequally rising portions of the sea-bottom which thus became portions of the respective continents: and they were compelled to either accustom themselves to the gradually freshening waters, from which they could not escape, or die. That many fresh-water forms have arisen by differentiation after their original progenitors were thus entrapped is evident: but this differentiation, at least among the Mollusca, has been slight and very slow, compared with what took place among the marine representatives of those classes during the same geological periods. Indeed a large number of the types among the Mollusca of the Mississippi drainage system have come down wholly unchanged from a time at least as remote as the Laramie Period.

Art. XLV.—*Measures of the Rings of Saturn in the years* 1879, 1880, 1881 and 1882: by Edward S. Holden.

In his memoir entitled *Recherches sur Saturne, ses anneaux et ses satellites* (1880), Mr. W. Meyer gives the results of his recent observations with the 10-inch equatorial of the Geneva Observatory.

Some of these results will not be received without criticism, since they go to show that the ball of Saturn is excentrically situated in the ring-system, and that the breadth of this system is not alike on the two sides. Specifically M. Meyer says, "je regarde donc comme établi par les observations qu' á l'époque où elles ont été faites, *la largeur de l'anneau de Saturne a été plus forte à son côté ouest, et que le centre même de la planète était plus près de l'extrémité est de l'anneau que l'autre.*" The results of his measures are given in table XI of his memoir, and in a table which accompanies the present note.



In order to make observations of this class readily comparable I have adopted a simple nomenclature which will cover all possible measures which can be made on Saturn. I have employed this in an extended examination of all the published drawings of Saturn known to me; and I take this opportunity of asking for a notice of the existence of rare drawings of Saturn, of those privately printed, and so forth. This system is shown in connection with a drawing of Saturn which was made at this observatory, 1881, November 27. The letters at the bottom of the drawing relate to points along the major axis of the ring.

a is the east end of the major axis.

b is the pencil line so-called (seen Nov. 27, 1881). It is too broad in the cut.

c is the *middle* of the principal division.

d is the point in ring B where the shading off begins; it is a definite point.

e is the outer edge of the dusky ring.

f is the inner edge of the dusky ring.

g is the east limb of the planet.

The remaining letters, *h* . . . . *n*, refer to the west half of the system.

Part.	W. Struve,* 1826.	Bessel, 1830-3.	Encke, 1837-8.	Galle, 1837-8.	Main, 1840.
ab	----	----	----	----	----
ac	2·61	----	2·76	3·36	----
ae	6·71	----	7·39	7·27	6·55
af	----	----	----	----	----
an	40·095	39·311	40·93	40·90	38·33
ag	11·05	11·13	11·63	11·50	11·37
c (width)	0·41	----	----	----	----
cd	----	----	----	----	----
ce	4·11	----	4·63	3·91	----
cf	----	----	----	----	----
ci	----	----	----	----	----
cl	34·882	----	35·41	34·18	----
de	----	----	----	----	----
ef	----	----	----	----	----
eg	4·34	----	4·24	4·23	4·82
ej	26·67	----	26·15	26·36	25·24
fg	----	----	----	----	----
fi	----	----	----	----	----
fl	----	----	----	----	----
gh	17·991	17·053	17·68	17·91	15·60
hi	----	----	----	----	----
hj	4·34	----	4·24	4·23	4·82
hn	11·05	11·13	11·63	11·50	11·37
ij	----	----	----	----	----
il	----	----	----	----	----
in	----	----	----	----	----
jk	----	----	----	----	----
jl	4·11	----	4·63	3·91	----
jn	6·71	----	7·39	7·27	6·55
kl	----	----	----	----	----
l (width)	0·41	----	----	----	----
ln	2·61	----	2·76	3·36	----
mn	----	----	----	----	----
Polar diam.	----	15·381	16·49	----	----

It is unnecessary to remind anyone who has looked over the great number of papers on Saturn, that for the want of a simple system of referring to the planet's features we are often in doubt as to what points, measures, and especially descriptions, refer. So far, we have only the nomenclature of Struve who called the outer ring A, the inner B, and the dusky ring C.

The accompanying table contains about all the useful measures which have been made on this system since 1826.

In the last column are given those of M. Meyer, which are by far the most complete as to scope, and which are still in progress. From these it will be seen that his measures place the ball of Saturn excentrically in the rings, and that the width of the ring system is not alike on both sides.

Of course, such conclusions need confirmation, as they are contrary to some of the most complete series of observations which we have.

Part.	O. Struve, 1852.	Lassell, 1852.	Jacob, 1853.	De la Rue, 1854.	Secchi, † 1854-56.
ab	----	----	----	----	----
ac	2·55	----	2·44	2·47	3·117
ae	7·42	----	6·80	6·46	7·590
af	9·46	----	8·87	----	9·738
an	39·73	40·881	39·91	39·83	40·893
ag	11·07	11·714	11·03	11·09	11·616
c (width)	----	----	0·37	----	----
cd	----	----	----	----	----
ce	4·87	----	4·36	3·99	4·473
cf	6·91	----	6·43	----	6·621
ci	27·74	----	28·61	----	28·040
cl	34·63	----	35·03	34·39	34·659
de	----	----	----	----	----
ef	2·04	[2·59]‡	2·07	----	2·148
eg	3·66	----	4·23	4·63	4·027
ej	24·90	----	26·32	26·91	25·714
fg	1·61	----	2·16	----	1·88
fi	20·83	----	22·19	----	21·419
fl	27·74	----	28·61	----	28·040
gh	17·59	17·453	17·86	17·66	17·661
hi	1·61	----	2·16	----	1·88
hj	3·66	----	4·23	4·63	4·027
hn	11·07	11·714	11·03	11·09	11·616
ij	2·04	[2·59]‡	2·07	----	2·148
il	6·91	----	6·43	----	6·621
in	9·46	----	8·87	----	9·738
jk	----	----	----	----	----
jl	4·87	----	4·36	3·99	4·473
jn	7.42	----	6·80	6·46	7·590
kl	----	----	----	----	----
l (width)	----	----	0·37	----	----
ln	2·55	----	2·44	2·47	3·117
mn	----	----	----	----	----
Polar diam.	----	----	16·51	----	----

* Bond's results are given in terms of $an = 1{\cdot}000$, and not in arc. To utilize them I have supposed $an = 40''{\cdot}47$, by which they become directly comparable with Mayer's, the most complete series.

† All the measures previous to 1880 I have treated on the supposition that they give a symmetrical figure to the system. I believe that the original measures of Struve (1826) and of Secchi (1854) differ slightly from this supposition, but as I have not access at present to th ir original papers, I have borrowed the data from Kayser's Memoir in the Leyden Observations, vol. iii.

‡ Lassell in 1852 wrote to O. Σ. that $ij = 0{\cdot}56\ hj$.

§ In Bond's later (unreduced) observations given in the same volume of the Harvard College Observatory Annals as his first, he usually estimates *ef* as less than one-half of *ge*.

I have made some measures of this system which are interesting in this connection, and which I shall give here although the series is not finished. They all relate to the position of the dusky ring C; and the position of the points *f* and *i* is invariably referred to (the *middle* of) the principal division, that is, to the points *c* and *l*. The observations were made in 1879 and 1880 with the 26-inch equatorial at Washington, and in 1881 and 1882 with the 15-inch equatorial here.

Part.	Bond,* 1848–56.	Jacob, 1856.	Kayser, 1862-3.	Meyer, 1880.
ab	----	----	----	----
ac	2·60	2·329	2·622	[3·00]
ae	6·96	6·863	5·806	6·97
af	9·31	8·892	----	9·88
an	40·47	39·997	39·471	40·47
ag	11·58	11·03	11·10	----
c (width)	0·47	----	----	----
cd	----	----	----	----
ce	4·36	4·534	3·184	[3·97]
cf	6·71	6·563	----	6·88
ci	28·57	28·777	----	[28·05]
cl	35·28	35·339	34·227	----
de	----	----	----	----
ef	2·35§	2·029	----	2·91
eg	4·62	4·166	5·292	4·45
ej	26·56	26·271	27·859	26·32
fg	2·27	2·14	----	----
fi	21·86	22·214	----	21·17
fl	28·57	28·777	----	27·58
gh	17·32	17·940	17·27	17·451
hi	2·27	2·14	----	----
hj	4·62	4·166	5·292	4·42
hn	11·58	11·03	11·10	----
ij	2·35§	2·029	----	2·24
il	6·71	6·563	----	6·42
in	9·31	8·892	----	9·42
jk	----	----	----	----
jl	4·36	4·534	3·184	4·18
jn	6·96	6·863	5·806	7·18
kl	----	----	----	----
l (width)	0·47	----	----	----
ln	2·60	2·329	2·622	3·00
mn	----	----	----	----
Polar diam.	15·46	----	15·392	16·021

These instruments are provided only with filar micrometers and are therefore not suitable for measuring diameters and distances such as occur in Saturn. This work properly belongs to the heliometer and the main part of it will undoubtedly soon be done at the Strassburg Observatory. But no heliometer now built has light enough to deal effectively with the dusky ring, and I therefore confined my measures with the Washington equatorial to that ring. The measures were referred

to the middle of the black division and not to some other point for obvious reasons.

All the distances were measured parallel to the major axis of the ring. In the Washington series they were single distances, each set usually containing four; at Madison all are double distances, four in each set.

I may add that it is my experience that the dusky ring is an object which requires to be *measured* under a high magnifying power, although it often seems to be better seen with a low one. As soon as measures commence, however, the advantages of the high power become apparent.

Observations of Saturn's Dusky Ring made with the 26-inch equatorial at Washington in 1879, *and reduced to* $\Delta = 9{\cdot}5389$.

No.	Date, 1879.	*lf*	*li*	*ci*	*cf*	Eye-piece	Wt.	*ci—lf*= *cf—li*=
			″		″			″
1	Sept. 10	----	6·88	----	7·02	400	4	+0·14
2	11	----	7·36	----	7·83	400	1	+0·47
3	16	----	6·83	----	7·45	400	2	+0·62
4	24	----	7·05	----	7·24	400	2	+0·19
5	25	----	7·31	----	7·69	400	4	+0·38
6	26	----	6·99	----	7·72	400	2	+0·73
7	29	----	7·07	----	7·58	600	4	+0·51
8	30	----	6·82	----	7·40	600	4	+0·58
9	Oct. 2	----	6·73	----	7·57	600	3	+0·84
10	5	----	7·12	----	7·65	600	4	+0·53
11	11	----	7·27	----	7·49	600	5	+0·22
12	14	----	6·86	----	7·63	600	3	+0·77
13	20	----	7·11	----	7·21	T.*	3	+0·10
	Means,	----	7·03 ± 0·04	----	7·50 ± 0·04			+0·47

Washington Observations of 1880 *reduced to* $\Delta = 9{\cdot}5389$.

No.	Date, 1880.	*lf*	*li*	*ci*	*cf*	Eye-piece	Wt.	*ci—lf*= *cf—li*=
		″		″				
14	Aug. 27	27·35	----	27·45	----	T.*	4	+0·10
15	27	27·62	----	27·58	----	400	4	−0·04
16	28	----	6·56	----	6·92	400	4	+0·26
17	Oct. 9	28·02	----	27·74	----	800	4	−0·28
18	10	27·44	----	27·74	----	800	4	+0·30
19	11	27·26	----	27·51	----	600	5	+0·25
	Means,	27·54 ± 0 09	6·56	27·60 ± 0·05	6·92			+0·10

* Terrestrial eyepiece magnifying 400 diameters.

Observations of Saturn's Dusky Ring made with the 15½*-inch equatorial of the Washburn Observatory in* 1881 *and* 1882, *reduced to* $\Delta = 9{\cdot}5389$.

No.	Date, 1881.	*if*	*ii*	*ci*	*cf*	Eye-piece	Wt.	*ci*—*if*= *cf*—*ii*=
			"	"	"			"
20	Dec. 8	----	----	27·81	----	260	3	cloud'd
21	8	----	6·35	----	6·66	260	3	+0·31
22	9	----	6·34	----	6·55	430	3	+0·21
23	14	----	6·52	----	6·70	430	2	+0·18
24	17	----	6·62	----	6·80	430	2	+0·18
25	18	----	6·36	----	6·60	430	2	+0·24
26	23	----	6·47	----	7·02	430	5	+0·55
27	23	----	6·15	----	6·15	T.*	5	+0·00
28	26	----	6·52	----	6·78	750	4	+0·26
29	26	27·80	----	27·88	----	750	4	+0·08
30	28	28·35	----	28·25	----	750	1	−0·10
31	30	----	6·76	----	6·94	430	2	+0·18
32	31	----	6·83	----	6·82	430	4	−0·01
33	31	27·96	----	28·05	----	430	4	+0·09
	1882							
34	Jan. 2	27·96	----	27·98	----	430	4	+0·02
35	3	----	6·47	----	6·86	430	3	+0·39
36	11	28·15	----	28·26	----	430	4	+0·11
37	Feb. 6	27·89	----	28·03	----	260	3	+0·14
38	7	27·83	----	28·23	----	260	3	+0·40
	Means,	27·99 ± 0·050	6·49 ± 0·040	28·05 ± 0·041	6·63 ± 0·051			+0·18
	No. obs.	(7)	(11)	(8)	(11)			(18)

I can say that the Washington observations were made under good circumstances, with sufficient magnifying powers and present a satisfactory agreement among themselves. (Their accidental errors are materially less than those of the Geneva series.) Also the Madison observations are entirely satisfactory to me. The difference between the two series is so far, not explained. A constant difference between the width of the rings B and C west and east is uniformly shown in both the Geneva and the other series.

The greater precision of measures having *i* as a terminal point will be noticed and it agrees with remarks made in my observing books.

According to M. Mayer	1880;	$cf-li = +0''{\cdot}46$
According to Washington	1879;	$= +0{\cdot}47$
According to Washington	1880;	$= +0{\cdot}10$
According to Madison	1881–2;	$= +0{\cdot}18$

It is somewhat remarkable that the four entirely independent series of observations agree in giving a value of *cf* materially larger than *li*. In the case of my own observations, I have

* Terrestrial eyepiece magnifying about 240 diameters. This power is too low for satisfactory measures.

been, and I am, somewhat skeptical as to the reality of this difference. In a system so complicated as that of *Saturn* constant errors may easily creep in. It was for that reason that I had constructed in Washington the terrestrial eye-piece which, unfortunately, I could use only on two nights. The terrestrial eye-piece for Madison is of too low a power for advantageous use, and I propose to replace it by one of higher power. By using this in connection with the regular astronomical eye-pieces, the existence of any personal difference which may exist between measures east and those west will show itself in the measures themselves, and I propose to carry these on until some satisfactory solution of these systematic differences is reached.

So far I have only considered the residuals *cf*—*li*, and they show a satisfactory agreement throughout my own three series and agree with those of M. Meyer. When we come to consider the absolute values of the things measured the discrepancies are relatively enormous. For example, *cf* in 1879 I found to be $7''.50 \pm 0''.04$ from thirteen nights, while in 1881 I found *cf* to be $6''.63 \pm 0''.051$ from eleven nights.

I can scarcely believe that even in these delicate measures I could make a constant error of nearly 1″ in arc in the measure of a distance of 7″. Nor can I accept the explanation that the distance *cf* has changed by 1″ in this time; certainly not without further proof. My reason for presenting the question in this unsolved state is that by so doing M. Meyer's conclusions may be examined more closely by those possessing large telescopes, and as other measures appear to present the same anomalies, certainly I shall endeavor to present further evidence on this point.

I do not believe that the difference in the telescopes employed has anything material to do with the difference in results. The edges of ring C were well seen in both telescopes.

I add a few measures of the position of belts on *Saturn's* surface made in 1878. I did not continue these measures longer as no useful result seemed to be promised.

Washington measures of Belts on Saturn.

Date, 1878.	Wash. m. t.		A	B
	h	m	"	"
Sept. 9	10	30	2·8	4·6
17	10	40	2·4	5·2
19	10	50	2·8	5·1
Oct. 1	11	30	2·4	5·2
8	10	50	2·8	--
14	9	30	2·2	5·1
21	8	30	2·6	--
25	9	18	2·6	4·7
26	9	36	1·8	4·3
Nov. 5	10	44	2·8	5·4::

N. B.--The measures in columns A and B are as follows: A=distances of the south edge of the bright equatorial belt of Saturn's southern hemisphere from the major axis of the ring; and B=distance of the center of the dark band in Saturn's northern hemisphere from the major axis of the ring.

I may add here that I have recently reduced the Washington observations of the position angle of the major axis of *Saturn's* ring and determined the inclination of the plane of *Saturn's* ring to the plane of the orbit of *Saturn*. The observations were made on seventy-seven nights in the years 1877, 1878 and 1879 which were favorable for this purpose. The 26-inch equatorial, the filar micrometer and eye-pieces magnifying from 400 to 800 times, were employed. The reductions have been made by Bessel's rigorous formulæ given in his *Abhandlungen*, vol. i, p. 321. The quantity sought is i', which is the inclination of the plane of *Saturn's* ring to the plane of *Saturn's* orbit; the results are as follow:

From the forty observations of Professor Hall we have for

1877·948=1877, Dec. 11; $i'=26°\ 38'\ 47''\pm1'·37$. The probable error of a single observation is $\pm8'·6$.

From the thirty-seven observations made by me we have for

1878·771=1878, Oct. 8; $i'=26°\ 57'\ 2''\pm1'·69$. The probable error of a single observation is $\pm10'·3$.

Bessel's twenty-two observations give

1818·726=1818, Sept. 20; $i'=27°\ 0'\ 9''\pm5'·2$. The probable error of a single observation was $\pm24'·1$.

I have not combined the results obtained by Professor Hall and myself since the observations of October 13, 14, 1877 and of November 13, 14, 1878, show that they are not comparable. My observations agree with those of Bessel within the limits of the probable errors. A comparison of the observations of Professor Hall with Bessel would indicate a diminution of the inclination since 1818.

Washburn Observatory, University of Wisconsin,
Madison, 1882, January 31.

Art. XLVI.—*Interference Phenomena in a new form of Refractometer;* by Albert A. Michelson.

In an experiment undertaken with a view to detecting the relative motion of the earth and the luminiferous ether (Am. Journal of Science, No. 128, vol. xxii,) it was necessary to produce interference of two pencils of light, which had traversed paths at right angles with each other. This was accomplished as follows: The light from a lamp at *a*, fig. 1, was separated into two pencils at right angles, *bc*, *bd*, by the plane-parallel glass *b*, and these two pencils were returned to *b* by the mirrors *c* and *d*, whence they coincided along *be*, where they were viewed by the eye, or by a small telescope at *e*.

It is evident that, so far as the interference is concerned, the apparatus may be replaced by a film of air whose thickness is *bc*–*cd*, and whose angle is that formed by the image of *d* in *b*, with *c*.

The problem of interference in thin films has been studied by Feussner, but his equations do not appear to give the explanation of the phenomena observed. In particular, in the "Annalen der Physik und Chemie," No. 12, 1881, on page 558, Feussner draws the conclusion that the interference fringes are straight lines, whereas, in the above described apparatus they are in general curves: and there is but one case—that of the central fringe in white light—which is straight.

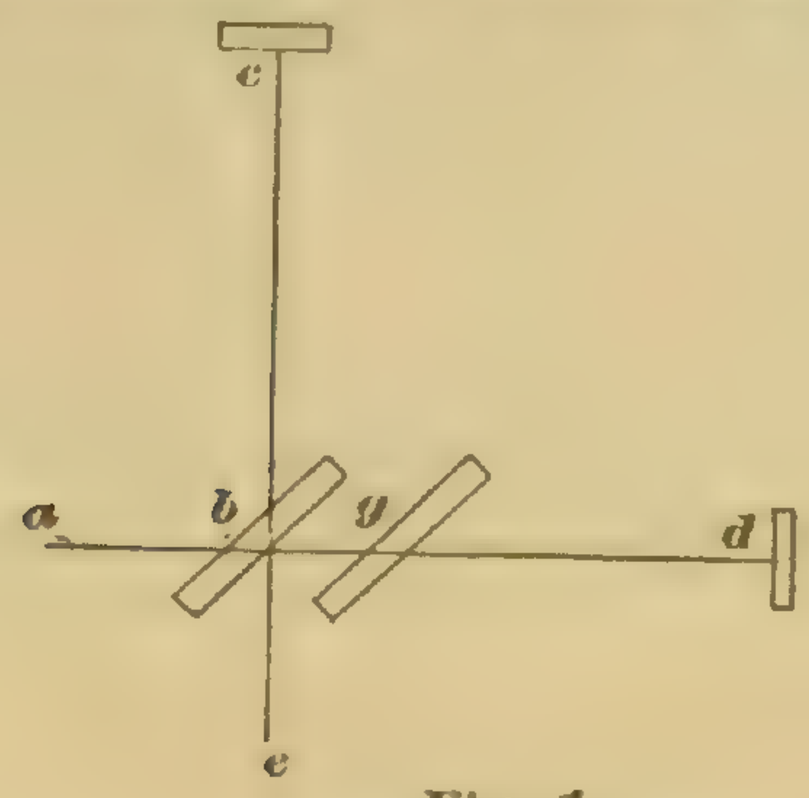


Fig. 1.

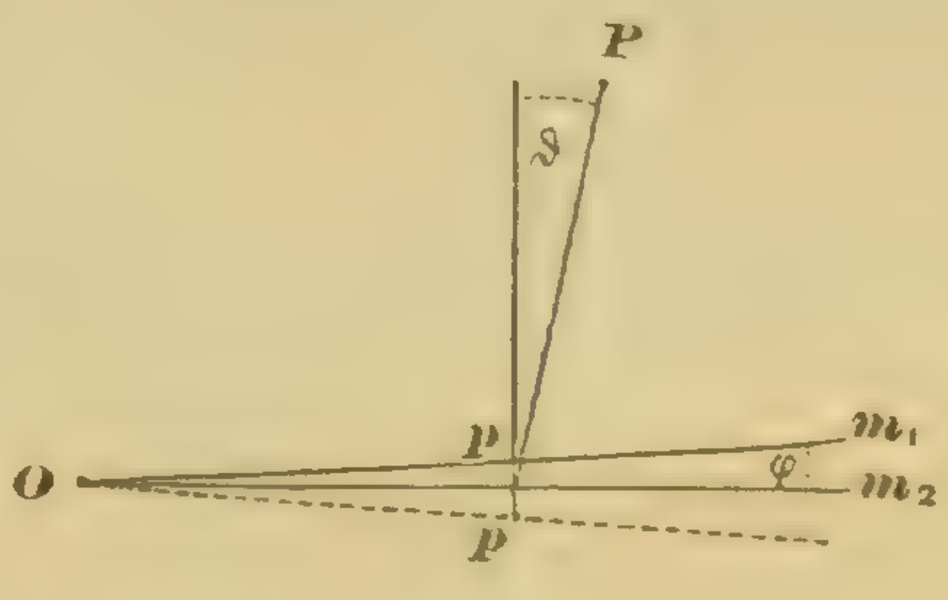


Fig. 2.

I have therefore thought it worth while to attempt the solution of the problem for a film of air, for small angles of incidence and neglecting successive reflections; and though the solution is not perhaps adapted to the general problem, it accounts for all the phenomena observed in the special case.

Let Om_1, Om_2, fig. 2, be two plane mirrors whose intersection is projected at O, and whose mutual inclination is φ. The illumination at any point, P (not necessarily in the plane of the figure), will depend on the mean difference of phase of all the pairs of rays starting from the source and reaching P, after

reflection from the mirrors; a pair of rays signifying two rays which have originated at the same point of the source.

If the area of the luminous surface is sufficiently large the illumination at P will be independent of the distance, form, or position of the surface. Suppose, therefore, that the luminous surface coincides with the surface Om_1. Its image in Om_1 will also coincide with Om_1, and its image in Om_2 will be a plane surface symmetrical with Om_1 with respect to the surface Om_2, and for every point, p, of the first image there is a corresponding point, p', of the second, symmetrically placed and in the same phase of vibration. Suppressing, now, the source of light and the mirrors, and replacing them by the two images, the effect on any point, P, is unaltered.

Consider now a pair of points pp'. Let ϑ be the angle formed by the line joining P and p (or p') with the normal to the surface; ϑ and φ being both supposed small,

$$\Delta = \mathrm{P}p' - \mathrm{P}p = pp' . \cos\vartheta .$$

The difference between this value of Δ and the true value is $2\mathrm{P}p . \sin^2\frac{\psi}{2}$, where ψ is the angle subtended by pp' at P. If ϑ is a small quantity, ψ is a small quantity of the second order, and $\sin^2\frac{\psi}{2}$ is a small quantity of the fourth order; consequently $2\mathrm{P}p\sin^2\frac{\psi}{2}$ may be neglected. We have therefore, to a very close approximation, $\Delta = pp'\cos\vartheta$; or, substituting $2t$ for pp', $2t$ being the distance between the images, at the point where they are cut by the line Pp,

$$\Delta = 2t\cos\vartheta .$$

Let *cdef*, *c'd'e'f'*, fig. 3, represent the two images, and let their intersection be parallel with *cf*, and their inclination be

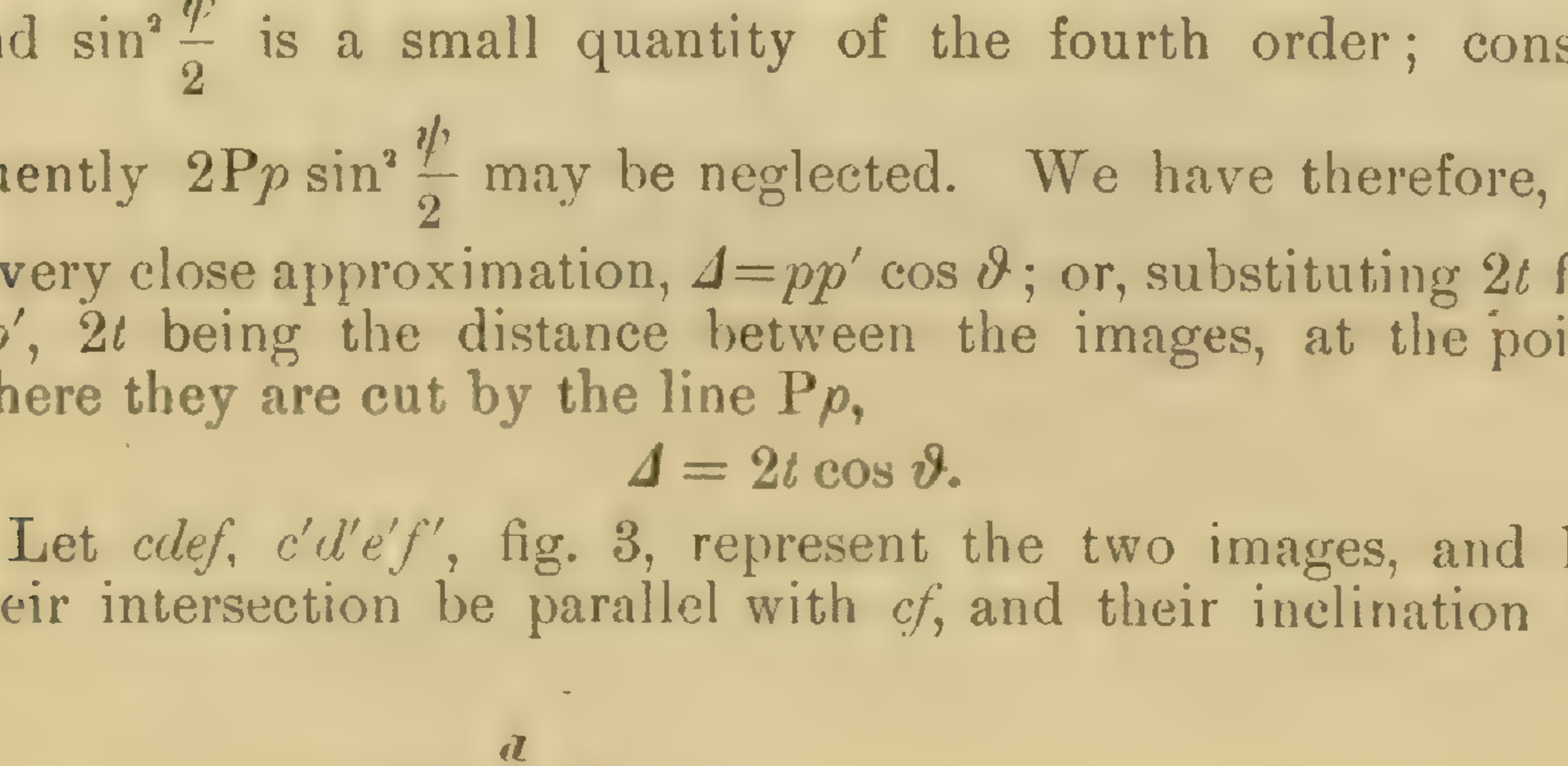


Fig. 3

2φ. Let P be the point considered; P′, the projection of P on the surface *cdef*; and PB, the line forming with PP′ the angle

ϑ. Draw P′D parallel to *cf*, and P′C, at right angles, and complete the rectangle BDP′C. Let P′PC$=i$ and DPP′$=\theta$. Let PP′$=$P, and the distance between the surfaces at P′$=2t_0$. We have then

$$t=t_0+\mathrm{CP'}.\tan\varphi=t_0+\mathrm{P}\tan\varphi\,.\tan i,\text{ and}$$

$$\Delta=2(t_0+\mathrm{P}\tan\varphi\tan i)\cos\vartheta,\text{ or}$$

$$\Delta=\frac{2\,(t_0+\mathrm{P}\tan\varphi\tan i)}{\sqrt{1+\tan^2 i+\tan^2\theta}} \qquad (1)$$

We see that in general Δ has all possible values, and therefore all phenomena of interference would be obliterated. If, however, we observe the point P through a small aperture, *ab*, the pupil of the eye, for instance, the light which enters the eye from the surfaces will be limited to the small cone whose angle is *b*P*a*, and if the aperture be sufficiently small the *differences in* Δ may be reduced to any required degree.

It is proposed to find such a distance P, that with a given aperture these differences shall be as small as possible, which is equivalent to finding the distance from the mirrors at which the phenomena of interference are most distinct. The change of Δ for a change in θ, is

$$\frac{\delta\Delta}{\delta\theta}=-\frac{2(t_0+\mathrm{P}\tan\varphi\tan i)\dfrac{\tan\theta}{\cos^2\theta}}{(1+\tan^2 i+\tan_2\theta)^{\frac{3}{2}}} \qquad (2)$$

The change of Δ for a change in i, is

$$\frac{\delta\Delta}{\delta i}=2\,\frac{(1+\tan^2 i+\tan^2\theta)\dfrac{\mathrm{P}\tan\varphi}{\cos^2 i}-(t_0+\mathrm{P}\tan\varphi\tan i)\dfrac{\tan i}{\cos^2 i}}{(1+\tan^2 i+\tan^2\theta)^{\frac{3}{2}}} \qquad (3)$$

For $\dfrac{\delta\Delta}{\delta\theta}=0$ we have $\theta=0$ (or $\Delta=0$).

For $\dfrac{\delta\Delta}{\delta i}=0$ we have $(1+\tan^2 i+\tan^2\theta)\,\mathrm{P}\tan\varphi$

$$=(t_0+\mathrm{P}\tan\varphi\tan i)\tan i,\text{ or}$$

$$(1+\tan^2\theta)\,\mathrm{P}\tan\varphi=t_0\tan i,\text{ whence }\mathrm{P}=\frac{t_0}{\tan\varphi}\tan i\cos^2\theta$$

Hence the fringes will be most distinct when $\theta=0$ and when

$$\mathrm{P}=\frac{t_0}{\tan\varphi}\tan i \qquad (4)$$

This condition coincides nearly with that found by Feussner.

If the thickness of the film is zero, or if the angle of incidence is zero, the fringes are formed at the surface of the mirrors. If the film is of uniform thickness, the fringes appear at infinity. If at the same time $\varphi=0$, and $t_0=0$, or $i=0$ and $\varphi=0$, the position of the fringes is indeterminate. If i has the

same sign as φ, the fringes appear in front of the mirrors; if i has the opposite sign, the fringes appear behind the mirrors.

To find the form of the curves as viewed by the eye at E, let SE=D; call T the distances between the surfaces at E′, the projection of E. From P draw PR parallel to DP′, and RS at right angles, and let RS=c. We have then $t_0 = T + c \tan \varphi$, whence, substituting for c its value D tan i,

$$\Delta = 2 \frac{T + (D+P) \tan \varphi \tan i}{\sqrt{1 + \tan^2 i + \tan^2 \theta}} \qquad (5)$$

If on a plane perpendicular to EE′ at distance D from E, we call x distances parallel to P′C, and y distances parallel to P′D, reckoned from the projection of E on this plane, then, putting tan φ=K and D+P=S, we have for the equation to the curves, as they would appear on this surface to an eye at E,

$$\Delta = 2 \frac{DT + SKx}{\sqrt{D^2 + x^2 + y^2}} \text{ or}$$

$$\Delta^2 y^2 = (4S^2K^2 - \Delta^2)x^2 + 8TSKDx + (4T^2 - \Delta^2)D^2 \qquad (6)$$

If, numerically,

$\Delta < 2SK$ the curve is a hyperbola,
$\Delta = 2SK$ the curve is a parabola,
$\Delta > 2SK$ the curve is an ellipse,
K=0 the curve is a circle,
$\Delta = 0$ the curve is a straight line,

All the deductions from equations (4) and (6) have been approximately verified by experiment.

It is to be observed that in the most important case, and that most likely to occur in practice, namely, in the case of the central fringe in white light, we have $\Delta = 0$, and therefore also $t_0 = 0$; and in this case the central fringe is a straight line formed on the surface of the mirrors. Practically, however, it is impossible to obtain a perfectly straight line, for the surface of the mirrors is never perfect.

It is to be noticed that the central fringe is black, for one of the pencils has experienced an external, the other an internal reflection from the surface b, fig. 1. This will not however be true unless the plate g (which is employed to compensate the effect of the plate b) is of exactly the same thickness as b, and placed parallel with b. When these conditions are not fulfilled, the true result is masked by the effect of "achromatism" investigated by Cornu (Comptes Rendus, vol. xciii, Nov. 21st, 1881). This remark leads naturally to the investigation of the effect of a plate of glass with plane parallel surfaces, interposed in the path of one of the pencils.

The effect is independent of the position of the glass plate, provided its surface is kept parallel with the corresponding mirror. Suppose, therefore, that it is in contact with the latter and let *cd*, fig. 4, represent the common surface. Let $t = hi =$ thickness of the glass, i=angle of incidence, r= angle of refraction, n=index of refraction, $\lambda =$ wave-length of light. Let *ef* represent the image of the other mirror, and put $n_0 = \frac{hk}{t}$.

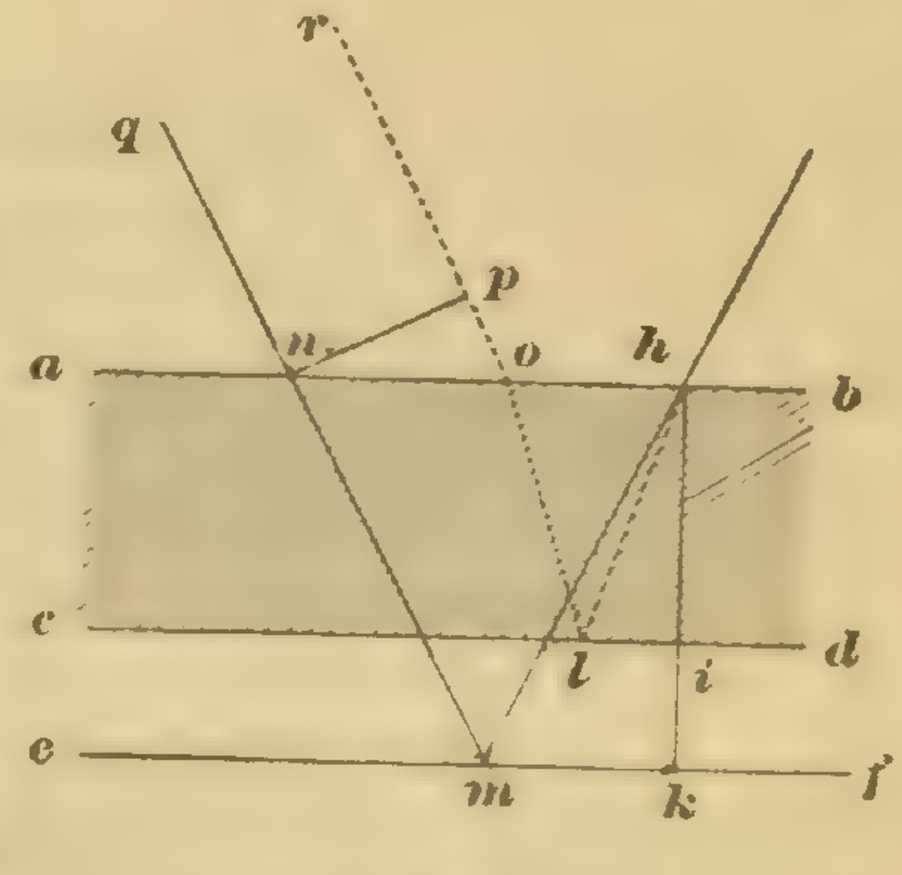


Fig. 4.

It can be readily demonstrated that the path of the rays in the instrument is equivalent to that given in the figure, where one of the rays follows the path *qnmh*, and the other the path *rolh*. Suppose the mirrors *cd* and *ef* parallel. Then as has been previously shown, the curves of interference are concentric circles, formed at an infinite distance. Therefore the rays *qn*, *ro*, whose path is to be traced, are parallel, and from the point *h* they coincide. Their difference of path is $2nm - 2hl - op$, and their difference of phase is

$$\varphi = \frac{2nm}{\lambda} - \frac{2hl}{\frac{\lambda}{n}} - \frac{op}{\lambda} = \frac{2n_0 . t}{\lambda \cos i} - \frac{2t . n}{\lambda \cos r}$$

$$- \frac{2t}{\lambda}(n_0 \tan i - \tan r) \sin i, \text{ whence}$$

$$\varphi = \frac{2t}{\lambda}[n_0 \cos i - n \cos r] \qquad (7)$$

Let it be proposed to find the value of n_0 which renders any particular ring achromatic. The condition of achromatism, as given by Cornu, is $\frac{d\varphi}{d\lambda} = 0$, which gives

$$\varphi + 2t\left(\cos r \frac{dn}{d\lambda} - n \sin r \frac{dr}{dn} . \frac{dn}{d\lambda}\right) = 0.$$

We have $n = \frac{\sin i}{\sin r}$ whence $\frac{dr}{dn} = -\frac{\sin^2 r}{\sin i \cos r}$, whence

$$\varphi + \frac{2t}{\cos r} . \frac{dn}{d\lambda} = 0$$

By Cauchy's formula we have $n = \alpha_1 + \frac{\alpha_2}{\lambda^2}$ whence $\frac{dn}{d\lambda} = -\frac{2\alpha_2}{\lambda^3}$.

Substituting, we have $\varphi - \frac{4\alpha_2 t}{\lambda^3 \cos r} = 0$ or $n_0 \cos i = n \cos r = \frac{2\alpha_2}{\lambda^2 \cos r}$

$$= \frac{\frac{2\alpha_2}{\lambda^2} + n \cos^2 r}{\cos i \cos r}$$, or finally,

$$n_0 = \frac{2(n - \alpha_1) + n \cos^2 r}{\cos i \cos r}. \qquad (8)$$

If the angle i is small, the value of n_0 will vary very little with i, consequently there will be a large number of circles all nearly achromatised. Under favorable circumstances as many as one hundred rings have been counted, using an ordinary lamp, as source of light. The difference of path of the two pencils which produce these rings in white light may exceed a thousand wave lengths.

ART. XLVII. — *On two New Minerals, Monetite and Monite, with a notice of Pyroclasite;* by CHARLES UPHAM SHEPARD; *with analyses*, by C. U. SHEPARD, Jr.

THE specimens here described were sent to us by Mr. John G. Miller of Ottawa, to whom Canadian mineralogy owes so many mineralogical discoveries. They came from the Twin islands, Mona and Moneta, which are situated forty miles from the port of Mayaguez, Porto Rico, W. I.

1. *Monetite.*—The Moneta mineral, which we call monetite from its locality, is accompanied by two other species; all of them, however, have originated together in a guano-formation. The prevailing rock of the island is probably a Tertiary marine limestone, which at the top of the ground has been coated with bird-guano. The soluble ingredients of this investment, in percolating the highly porous strata, have been thrown down in their transit in the metamorphosed combinations now met with, lining the walls of cavities in the formation.

The material supplied came from one of these caverns. The specimens present a remarkable feature, as compared with the stone-guanos of the West Indies. The latter are usually uncrystalline, more or less compact, heterogeneous in their composition; and contain considerable traces of organic matter. They very rarely present dissociated simple minerals; but rather constitute what are called rock-aggregates. The examples from Mona, on the contrary, are almost wholly made up of distinctly separate mineral species, for the most part are crystallized, and as free from organic impregnation as if derived from trap or granite. The most abundant species in

the specimens received, is the monetite which sometimes forms isolated patches, half the size of one's hand. The second constituent of the masses is a snow-white gypsite, either crystallized, fibrous or pulverulent; while the remaining one is calcite, in well-formed, semi-transparent crystals. No alumina or oxide of iron is present in the aggregate.

The monetite, besides occurring in thick isolated masses as above mentioned, also forms irregular seams through the gypsite; and shows itself likewise in thick crusts, lining irregular shaped cavities. More rarely, it presents itself in botryoidal shapes, with rough crystalline surfaces. But under all circumstances, it is an highly crystalline mineral.

Mineralogical description.—Primary form,* right oblique angled prism. M on T about 143° as determined approximately by the common goniometer. Secondary forms, terminal and acute lateral edges replaced by single planes, the former generally very narrow. Height of prisms less than one-third their longest breadth; sometimes much less. Greatest length of crystals between $\frac{1}{12}$th and $\frac{1}{20}$th of an inch. They exhibit numerous irregular surface indentations, but are without striæ or curvatures. They cross and interpenetrate each other in several directions, some of the groups suggesting a regular composition of individuals. Though exhibiting frequent rifts, the cleavage is indeterminate. Fracture, uneven. Luster, vitreous. Semi-transparent. Color, pale yellowish white. Hardness =3·5. Gravity =2·75, which is a little below the actual, from the impossibility of wholly clearing the crystals of the mealy white monite and gypsite by which they are more or less coated.

Before the blowpipe, heated in a glass tube, turns white and evolves moisture, but unattended by odor. In the platinum forceps, turns white and melts into a globule with crystalline facets.

Analysis.

	I.	II.	Mean.
Lime	39·92	40·59	40·255
Phosphoric acid	44·41	49·79	47·100
Sulphuric acid	7·20	1·90	4·550
Water	8·47†	7·88	8·175
	100·00	100·16	100·080

4·55 per cent sulphuric acid calls for 3·185 per cent lime and 2·047 per cent water; thus constituting 9·782 per cent of gypsite. The mineral lost 0·2 per cent of moisture on drying it several hours at nearly 100° C. Subtracting the above constituents we have:

* See also the note on the crystalline form by E. S. Dana, on p. 405.

† The water in the first analysis was estimated by difference.

Phosphoric acid	47·100
Lime	37·070
Water	5·928
	90·098

And raising the above figures to 100, we have as the composition of the *monetite*,

Phosphoric acid	52·28
Lime	41·14
Water	6·58
	100·00

Dividing the above percentages by the respective molecular weights, we have:

Phosphoric acid	$52·28 \div 142 = 0·368$
Lime	$41·14 \div 56 = 0·735$
Water	$6·58 \div 18 = 0·366$

or very nearly, as 1 phosphoric acid: 2 lime: 1 water. This would require the formula $2CaO, H_2O, P_2O_5$ (or $CaHPO_4$), as a comparison of the calculated and obtained results will show.

	Calculated.	Found.
Phosphoric acid	52·20	52·28
Lime	41·18	41·14
Water	6·62	6·58
	100·00	100·00

Monetite is a crystalline dicalcic-hydric-phosphate, or dicalcic-ortho-phosphate, differing from that artificially prepared (by the action of calcic chloride on disodic-hydric-phosphate), in not possessing water of crystallization as does the latter—$(PO_4H)_2 Ca_2+2H_2O$.

2. *Monite.*—Intimately associated with the monetite, above described, is a hydrated tricalcic phosphate, resembling in color and density the more friable varieties of kaolinite, and which we propose to designate *monite*, after one of the islands where it is found. It has the following characters:

Massive, slightly coherent, impalpable and wholly uncrystalline; snow-white, fracture earthy, dull; hardness, below 2, gravity 2·1 (approximately). B.B. melts with difficulty to an opaque, white enamel of feeble luster. In closed tube emits much moisture.

Analyses.

				Mean.
P_2O_5	40·39	39·44	39·75	39·86
CaO	50·04	50·89	49·51	50·15
SO_3		2·57	1·75	2·16
H_2O			7·56	7·56
				99·73
Deducting				
2·16 SO_3=1·51 CaO=0·97 H_2O=gypsite,				4·64
				95·09

	Remaining.	Raised to 100.	Molecular weights.	Approximate ratios.
P_2O_5	39·86	41·92	÷ 142 = 0·295	1
CaO	48·64	51·15	÷ 56 = 0·913	3
H_2O	6·59	6·93	÷ 18 = 0·385	1¼
	95·09	100·00		

Or corresponding to $Ca_3P_2O_8+H_2O$ with some slight excess of moisture, probably hygrometric.

The two minerals, monite and monetite, are much intermingled, constituting together three-quarters of the variously sized masses, whose remaining quarter consists of gypsite and calcite, the latter however in isolated patches and in much the least proportion. The remarkable feature of the aggregate as coming from a stone-guano formation, consists in the entire absence (in masses, half a foot in thickness), of all traces of organic matter. The monetite is the most abundant species, sometimes occupying areas several inches long by one or two broad: and inasmuch as its crystals are confusedly aggregated and rather sharp, the specimens are exceedingly rough to the touch. The interspaces between the crystals occupy as much room as the crystals themselves; and are more or less filled with the monite. When the intervals are completely occupied with the latter, the aggregate is often arranged in imperfect layers, separated by intervals of about one-sixth of an inch, filled by the monite. A cross-fracture of such masses displays an obscurely banded appearance. Rarely the monetite presents globular concretions, with a sub-fibrous structure. It is also sometimes granular, but when pure it is rarely impalpable.

The associated gypsite is white, in small shining crystals, in coarse fibrous individuals, small globules, fine granular and pulverulent. The calcite is in distinct, semi-transparent crystals, having the form of acute rhomboids, analogous to those resulting from the slow evaporation of brine-waters. The presence of silica, or some insoluble silicate is detected in the analyses of the aggregate only, where it varies from 0·5 to 2· per cent.

Pyroclasite.—As the series of specimens sent were said to have been from caves, which abound at these islands, it would appear that their contents originated in percolations across the Tertiary strata. Indeed, examples of the lime-rock are among the collection, evincing the progress of metamorphosis from the unaltered calcic carbonate, to entire calcic phosphate. Wherever the solutions in their descent encountered caves or open joints in the strata, stalagmite and incrustations would result. Several specimens of these were among the collection sent. They strongly resemble the impure stalagmites of our limestone caves. Portions of the guano-stalagmite are singularly in the shape of mushrooms; and must have occupied the surface of the floor-crust. When broken, their structure is seen to be concentrically laminated, and not fibrous. In color they are brown, intermingled in spots with ash-gray, suggestive of a composite constitution. Other masses appear to have come from the floor stratum itself; and are hard and compact, with a subconchoidal fracture, like the monetite and like some varieties of opal. Its color is brown, though much darker and occasionally almost black. It is moreover variegated with ash-gray. The specific gravity is 2·62–2·65: hardness, 3·5–4·0. B.B. it decrepitates, emits a decidedly organic odor, turns white and fuses, but less easily than monetite, to a white, shining enamel. Heated in a glass tube, it decrepitates, with liberation of much water and strong empyreumatic odor. The subjoined analyses give its chemical composition.

	Robertson.	Shepard.	Mean results.
P_2O_5 .....(total)	40·81	38·80	39·080
CaO	40·27	39·98	40·125
SO_3	6·85	6·80	6·825
Phosphate iron and alumina		2·90	2·900
Insoluble	0·58	1·13	0·855
Water and loss on ignition..	9·76	10·91	10·335
	98·27	100·52	100·120

Deduct gypsite	14·670	
" insoluble	0·855	
" phosphates iron and alumina	2·900	
" ⅓ of loss by ignition, as organic	2·422	
		20·847
		79·273

This raised to 100 gives

			Calculation requires
P_2O_5	38·08	49·30 ÷ 142 = 0·347	49·05
CaO	35·35	44·59 ÷ 56 = 0·796	44·06
H_2O	4·84	6·11 ÷ 18 = 0·339	6·29
	79·27	100·00	100·00

Admitting the following formula:

$$3(Ca_2H_2P_2O_8)+Ca_3P_2O_8+H_2O.$$

The substance above analysed is undoubtedly identical with that from Monk's Island (Caribbean Sea) described in 1856, in this Journal, vol. xxii, p. 97, and named pyroclasite, from its very striking property of decrepitation when heated.* Whether it forms a true mineral species must depend upon more extended examinations. The analyses given favor the idea of its being an uniform compound of monetite and monite. It may, however, prove only a mechanical mixture of the two. Whether chemical or mechanical, it is eminently prone to admixture with gypsite, aluminum and iron phosphates, silica and organic matter, constituting the important phosphatic rock of the West Indies and South Carolina.

It may be added in conclusion that the collection embraced several specimens of antillite, which is identical with the trappean rock mentioned in connection with the pyroclasite of Monk's Island.

* An associated mineral which I then examined and called glaubapatite is essentially the same thing; the soda found therein having without doubt been owing to the damaged state of the cargo from which it was taken. The vessel that brought it to this place was bound for Baltimore; but was compelled, from damage at sea, to put into this port. The sulphuric acid found in the mineral was erroneously dosed with soda instead of lime. With the correction of these errors of analysis I desire to withdraw the name glaubapatite. The mineral to which it was given comes under pyroclasite.

Note on Crystals of Monetite.—The crystals of monetite placed in my hands may with tolerable certainty be referred to the triclinic system. The general form is that of a rather thin rhomboid. The longer lateral edge is replaced by the plane 100 (*a*), and the shorter by the hemi-prism $1\bar{1}0$ (*I*); there are also present in this zone the brachypinacoid 010 (*b*), and two other hemi-prisms *hko* (*m* and *n*) between 100 and $1\bar{1}0$, and a third *hko* (*l*) on the other side of 100. The top of the tabular crystals is formed by the basal plane 001 (*c*) which is rough and uneven, and the edge behind, between *a* and *c*, is replaced by a dome $\bar{1}01$ (*e*). The angles measured with a reflecting goniometer are only roughly approximate, and would not justify an attempt to calculate the axial ratios and inclinations. The supplement angles are: aI ($100 \wedge 1\bar{1}0$) = 42°, ab ($100 \wedge 0\bar{1}0$) = 81°, am = 17°, an = 28°, al = 18°, ac = 76°, ae ($100 \wedge \bar{1}01$) = 138°. There appears to be a distinct cleavage parallel to *a*. The crystals often interpenetrate each other, forming complex groups, but there is no uniform law of composition.—E. S. Dana.

Charleston, Feb. 18, 1882.

ART. XLVIII.—*Notice of the remarkable Marine Fauna occupying the outer banks off the Southern Coast of New England, No. 6*: by A. E. VERRILL. (Brief Contributions to Zoology from the Museum of Yale College: No. LII.)

Parasmilia Lymani Pourtales.—*Remarkable modes of growth and repair.*

POURTALES mentions that in this cup-coral the young bud out from the inside of the parent-calicles and burst them, by their normal growth. So that, afterwards, they remain attached to fragments of their own parents. This is probably an erroneous explanation of facts identical with some of those that I have observed. We have dredged this coral in considerable numbers, and of larger size than those described and figured by Pourtales. In each locality nearly all the specimens are attached, at base, to the inner surface of fragments, more or less old and discolored, of the same coral, as observed by Pourtales. Moreover, we have been able to collect a series sufficient to fully demonstrate that all these cases are instances of buds arising from the inner or septal surfaces of such specimens as have been accidentally broken or crushed. The coral is very fragile and has a tendency to split longitudinally into wedge-shaped segments when it breaks. Each fragment then has the power of developing from its still living internal tissues, and especially from the membrane (endoderm) covering the septa, one or more buds, which then grow up into cornucopia-shaped cups, like the parent. In many specimens a single large bud will start from near the distal end of a large piece; such a bud will grow up into a regular, more or less curved, circular or elliptical cup, with a thick base, continuous in part with the original fragment: the costæ and septa of the old fragment are perfectly coincident with the costæ and septa of the new coral on the outer or marginal side; examples of this kind, in all stages of development, were taken; one of these buds is 14^{mm} broad at base and 17^{mm} high on the proximal side, 7^{mm} high on the distal side; another is 13^{mm} broad at base and 23^{mm} high; another is 10^{mm} broad at base, 22^{mm} high, the circular calicle 14^{mm} broad; another is 6^{mm} broad at base, 44^{mm} high, the elliptical calicles 20 by 25^{mm}. In several cases two buds starting close together, from a single fragment, or from two imperfectly separated pieces, have grown together more or less completely, so as to produce a double calicle, the two halves either equal or unequal, and separated by a constriction, but with two septal centers and columellæ, and two distinct mouths. The largest example of this kind is 50^{mm}

high, the two calicles together, 40mm across, each one about 20mm broad. In one instance the base of a good-sized cup has been broken off, where about 6mm in diameter: from the broken and ragged ends of the septa thus exposed three buds have started out, each 3 to 4mm broad, with 24 to 36 septa: the old calicle appears to have been unaffected. In another instance a calicle that had developed, as usual, from a fragment, after it had grown 22mm high was itself badly injured, so that half of the interior of the calicle died, but was not broken, but from the other half a large bud arose, nearly filling the old calicle by its new growth, and soon becoming larger than before the injury, so that on one side the cup is nearly regular and the costæ continues to the base, while on the other side the edge of the old calicle, with the old septa in place, appears in high relief, at about mid-height of the cup: in this case we have, as it were, three generations shown in one specimen; this example is 45mm high, the calicle 25mm broad. One of the most remarkable examples is a large cup, 50mm high and 28mm broad, in which the inner margin and distal portion of the septa are discolored, indicating that the soft parts within the edge of the calicle, and probably the tentacles, disk and stomach had been destroyed by access of mud, or some other accident, while the parts farther within the deep cup, or at least the membranes there covering the walls and septa, remained alive; from the edges and surfaces of the septa over thirty small buds have started out, varying in size and degree of development; the greater number form a partial circle, 10 to 12mm from the margin, but others are scattered over the more interior parts of the cup, even to very near its base, the columella being nearly absent: the larger of these buds are about 5mm in diameter, but some are not more than 2mm, and many are just beginning to appear, and have slight walls and septa only on one side. In all cases the still living edges of the old septa serve as some of the septa of the new growth.

A number of large specimens were dredged, off Chesapeake Bay, in 57 fathoms (station 899) by Lieut. Z. L. Tanner, on the "Fish Hawk," Oct., 1880. It was dredged by our party, on the "Fish Hawk," off Martha's Vineyard, in 100 to 130 fathoms (stations 940, 949 and 1040), in 1881. It was more common and largest at station 940, in 130 fathoms. Off Florida,—Pourtales.

In speaking of *Flabellum Goodei* (p. 313), I have mentioned that it also has this same mode of budding from the inner surface of the fragments. Some of these phenomena have been noticed in other deep-sea corals, though not explained in the same way. Probably this will, hereafter, be found to be a common mode of increase in the case of various fragile cup-

corals. Indeed, I believe that the same explanation will apply to some of the ancient cyathophylloid corals, in which buds arise within and appear to destroy and supplant the parent calicle. Instead of such buds being the *cause* of the *death* of the parent-polyp, as has been supposed, I believe them to be due to the *result* of injury and the consequent effort of the tissues to *retain life* and repair injuries.

Restoration of the disk in Ophiurans.

That Ophiurans restore their rays with remarkable facility when broken, or entirely lost, is well known. In examining a large series of *Amphiura abdita* V., collected in the harbor at Noank, Conn., among eel-grass (*Zostera*), in 1874, I found several specimens in which the entire dorsal disk, with the contained viscera, had been lost and more or less restored, showing the various stages of the process. The dorsal disk of this species is soft and swollen, and is very easily detached. The arms are exceedingly long and slender and subject to frequent restorations. In some of the examples in which a new disk was forming, the scars are still plainly visible, on the bases of the arms, showing where the disk had been torn away, and its former size. In some of these the new disk, though perfect in form, had not grown to more than one-third, or one-half the diameter of the old one; in others it was nearly completed. These small disks connected with the full sized arms and jaws of the adult, give such specimens a very peculiar appearance. At first I mistook some of these for the genuine young.* But a more careful examination easily revealed their true nature.

In the same lot were specimens in which a portion of the edge of the disk, with one or two of the arms, had been destroyed, and afterwards restored. In a few instances two arms had grown out, in place of one.

* It is quite probable that *Amphiura mucilenta* V., described in the February number of this Journal, p. 142, is really the true young of *A. abdita*. There are no *genuine young* of the shallow-water form known to me. The restored specimens, with small disks, appeared so different that, until I discovered their true nature, the identity of the two forms did not seem to me possible.

ERRATA.

Page 309, line 26, for *Ballicina*, read *Balticina*.
Page 313, line 7 from bottom, for S. O. Sars, read G. O. Sars.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the determination of Gas-densities.*—Goldschmidt and Victor Meyer, having occasion to make a series of determinations of the density of cyanogen gas at various temperatures, contrived for this purpose a simple method. The gas vessel is filled first with pure dry air at the temperature at which the determination is to be made. Then this air is displaced by a current of hydrogen chloride gas, collected over water and measured. Next the hydrogen chloride is displaced by air. After this the gas to be examined is passed through until all the air is replaced by it. This gas is again displaced by hydrogen or air and collected in a potash bulb filled with a liquid which absorbs it completely. The increase of the weight of the bulb gives the weight of the gas. The weight of the vessel full of air and of gas being now known for the given temperature the density is easily obtained. The apparatus consists of a cylinder of glass 200^{mm} high, 30^{mm} diameter, with capillary tubes attached to the ends, rising considerably above the upper end of the cylinder and there bent each at right angles. This vessel is heated in a glass tube slightly bulbous at bottom, 400^{mm} high and about twice the diameter of the inner tube, containing the liquid whose boiling point is the temperature of measurement. Water, aniline, amyl benzoate and diphenylamine are used in the glass outer vessel; but at temperatures of boiling sulphur or phosphoric sulphide, the inner vessel is spherical and the outer one of iron. Carbon dioxide and hydrogen chloride gases gave in this apparatus densities of 1·53 and 1·26 respectively. The apparatus may obviously be used as an air thermometer; and the authors determined the boiling point of sulphur as 426° C.—*Ber. Berl. Chem. Ges.*, xv, 137, Feb., 1882.

G. F. B.

2. *On the diffusion of Solids into Solids.*—Colson has observed that if an iron plate is heated in lampblack not only the carbon penetrates into the iron, converting it into steel and then into cast iron, but also considerable quantities of iron diffuse into the carbon. If the heating be sufficiently prolonged, this diffusion may be shown to take place even at 250°. If a piece of piano wire, imbedded in lampblack, be heated to redness in the reducing flame, it loses weight. Platinum under these circumstances shows no change. Since platinum does not combine with carbon, it appears that a diffusion occurs between solids only when they can react on one another. Pure silver loses weight when heated in pure dry alkali-chloride. But the product darkens on exposure to light; hence silver chloride must have been formed, free alkali having been produced by the oxygen of the air. If a polished piece of artificial iron sulphide be heated on a plate of copper in a current of CO_2 small quantities of sulphur go from the iron to the

copper. If a piano wire be heated in a crucible lined with carbon and filled with lime, the wire increases in weight and shows on analysis the presence of calcium.—*C. R.*, xciii, 1074. G. F. B.

3. *On the production of Active Oxygen.*—TRAUBE has summed up the conclusions upon the production of active oxygen to which he has been led by his experiments. He finds (1) that hydrogen-palladium, agitated with water and oxygen (or air) produces immediately and abundantly hydrogen peroxide; (2) that the oxidizing action of hydrogen-palladium in presence of oxygen and water, is not a direct one but depends almost entirely upon the hydrogen peroxide thereby produced; (3) that only in a single case has he observed the oxidizing action of hydrogen-palladium to be different from that of hydrogen peroxide; iodide of potassium and starch, which is not blued by H_2O_2, is blued at once by the hydrogen-palladium and oxygen; evidently by the carrier-action of the palladium transferring oxygen from the hydrogen peroxide to the potassium iodide; (4) that the experiments prove positively, in opposition to the view of Hoppe-Seyler, that nascent hydrogen cannot produce active oxygen from ordinary oxygen by splitting its molecule; and (5) that the frequent production of hydrogen peroxide in processes of oxidation is no evidence of the simultaneous presence of active oxygen, because in opposition to the common view, the peroxide is never produced by the oxidation of water by active oxygen. It is a reducing action which produces it even when the process in general is one of oxidation. Thus for example when zinc is agitated with water and oxygen, there is produced, beside zinc hydrate, also hydrogen peroxide. But no active oxygen is formed, the molecule of oxygen not being split, but the molecule of water, its oxygen combining with the zinc to form the hydrate, its hydrogen uniting directly with the oxygen molecule to form hydrogen peroxide, thus:

$$Zn+(H_2O)_2+O_2=Zn(OH)_2+\begin{matrix}O-H\\ |\\ O-H\end{matrix}.$$

Hydrogen peroxide is produced by the union of a molecule of oxygen with two atoms of hydrogen. By analogy with other bodies produced by reduction, *i. e.*, assumption of hydrogen, it might be called reduced oxygen. It behaves toward common oxygen as indigo-white to indigo-blue.—*Ber. Berl. Chem. Ges.*, xv, 222, Feb., 1882. G. F. B.

4. *On the so-called Persulphuric oxide of Berthelot.*—Since by the mode of its production as well as by its reactions and properties, the body discovered by Berthelot, and called by him persulphuric oxide, resembles the peroxides, such as H_2O_2, BaO_2, etc., MENDELEJEFF prefers the name sulphur peroxide for it. The bodies MnO_2 and PbO_2, which form salts, he would call dioxides only. The blue Cr_2O_7, the highest stage of oxidation of chromium must be viewed as chromium peroxide, or chromyl peroxide. According to the author's view, an element, according to its character, gives either basic or acidic oxides which possess the property of forming salts corresponding to the water type, and accord-

ing to which the so-called valence of the elements or their position in the system, is determined. Only after the production of the oxide forming the highest salts, can the element yield a peroxide of the type of hydrogen peroxide. There is no ground for the assumption that hydrogen, barium, etc., can give still higher stages of oxidation, and then perhaps yield acidic oxides. Sulphur peroxide confirms this view completely and leads to the expectation of the discovery of similar peculiar peroxides with many of the other elements.—*Ber. Berl. Chem. Ges.*, xv, 242, Feb., 1882.

G. F. B.

5. *On the production and properties of metallic Cæsium.*—Setterberg has worked up the tons of alums obtained in Marquart's laboratory as a by-product in the preparation of lithium salts from lepidolite, with a view to obtain larger quantities of the salts of cæsium and rubidium and if possible metallic cæsium itself. Three or four hundred weight of the alums were dissolved in so much water that at the boiling temperature, the liquid marked 20° B. The solution was decanted and allowed to stand 12 to 14 hours. The mother liquid contained no trace of cæsium or rubidium salts but the crystals were rich in these metals; the author having found that each of the different alums is insoluble in saturated solutions of the more soluble ones. Hence so long as the solution of the alums was saturated with potassium alum it contained scarcely a trace of the other alums; and the solution showed no trace of cæsium, so long as it was saturated with rubidium alum. By repeating this process the alums were obtained pure. Search for other alkali-metals gave a negative result. In 14 days, Setterberg prepared 40 kilograms rubidium alum and 10 kilograms cæsium alum both pure. At 17° C. 100 parts of water dissolved 1·42 parts of rubidium alum and 0·38 parts of cæsium alum. For the preparation of other salts, the alums were decomposed with barium hydrate, and the filtrate neutralized with the acid whose salt was desired. In this way the acid tartrates and the cyanides were prepared. For the preparation of metallic rubidium, 1500 grams hydrogen-rubidium tartrate, 150 grams calcium carbonate and the required quantity of sugar were mixed and calcined and the mixture transferred to a mercury flask and distilled. The yield was very satisfactory. A kilogram of hydrogen-cæsium tartrate similarly treated afforded no result. The electrolytic method was then employed first with the chloride and then with the cyanide of cæsium. Finally a mixture of 4 molecules of cæsium cyanide and one of barium cyanide was found to give a satisfactory result, the metal prepared showing in the spectroscope only a trace of sodium as an impurity. Cæsium resembles closely the other alkali-metals. It is silver-white, malleable and very soft at ordinary temperatures. Thrown on water it bursts into flame, and swims about on the surface like potassium and rubidium. It inflames in the air when not protected. It fuses about 26·5°, passing through a pasty condition. Its specific gravity is 1·88 at 15° C.—*Liebig's Ann.*, ccxi, 100, Jan., 1882.

G. F. B.

6. *On the metals of the rarer Earths.*—The position of the cerite metals in the periodic series of Mendelejeff has been for a long time a subject of discussion. BRAUNER has made a special study of these elements with reference to this point. With cerium he succeeded in preparing the tetrafluoride CeF_4, H_2O, as an amorphous brown powder, and a double fluoride $(KF)_3(CeF_4)_2(H_2O)_2$, as a yellowish white crystalline powder. With didymium, he prepared the hydrated pentoxide Di_2O_5, H_2O, and also the anhydrous pentoxide. The atomic weight of didymium was determined as 146·18 and that of lanthanum as 139. Hence the author places cerium (atomic weight 141·6) in the fourth group, eighth series, didymium in the fifth group, eighth series, and lanthanum in the third group, eighth series. This places Ce with C, Si, Ti, Zr, Sn, Pb and Th; and didymium with N, P, V, As, Cb, Sb and Bi.—*J. Chem. Soc.*, xli, 68, Feb., 1882. G. F. B.

7. *On the preparation of Cymene from Turpentine.*—NAUDIN has pointed out a reaction by which cymene can be prepared from turpentine with great facility. If two atoms of dry chlorine are absorbed by one molecule of turpentine cooled to -15°, there is no sensible evolution of hydrogen chloride but the liquid becomes viscous and contains $C_{10}H_{16}Cl_2$. A slight elevation of temperature produces decomposition, and cymene and hydrogen chloride distill together. If to the mixture 4 per cent. of phosphorous chloride be added, and the temperature be maintained at 25°, a regular evolution of HCl takes place until the conversion is complete. Washing with water, drying over calcium chloride and rectification over sodium, gives pure cymene boiling at 175°, the yield being 75 per cent. The author has observed that at 100° traces of zinc dust violently decompose the body $C_{10}H_{16}Cl_2$.—*Bull. Soc. Ch.*, II, xxxvii, 110, Feb., 1882. G. F. B.

8. *On a new Alkaloid from Cinchona Bark.*—In investigating the alkaloids of the variety of cinchona bark described by Flückiger as *China cuprea*, HOWARD and HODGKIN have obtained an alkaloid which appears peculiar to that species. This bark has recently been shipped in immense quantities from Bucarramanga in the province of Santander, where this tree is said to form whole forests. It yields from none up to 2 per cent of quinine, and small amounts of quinidine and cinchonine. The new alkaloid is in its properties analogous to quinine, having a composition nearly identical and nearly the same specific rotary power. It differs however in the solubility of its salts and in the readiness with which it crystallizes from ether. The authors propose for it the name *homoquinine*. The alkaloid itself dissolves very sparingly in ether, 100cc dissolving only 0·57 at 12°. Alcohol of 90 per cent dissolves 7·64 parts. The sulphate resembles that of quinine, but the crystals are shorter and appear to contain 6 molecules of water. One part of this salt requires more than 100 of water for solution. In a 5 per cent solution of 90 per cent alcohol the alkaloid shows a rotation of -158°.—*J. Chem. Soc.*, xli, 66, Feb., 1882.

G. F. B.

9. *On the Coloring matter of the Chinese yellow berries.*—Foerster has examined the Chinese yellow berries used in dyeing (the buds of *Sophora japonica*). The glucoside obtained when treated with sulphuric acid yielded 46·84 per cent of a yellow substance and 57·56 per cent of isodulcite. This yellow substance was not quercetin however; and so the glucoside is not quercetrin. The author proposes for it the name sophorin. The glucoside of the caper (*Capparis spinosa*) and of the garden rue (*Ruta graveolens*) are apparently identical with quercetrin, yielding quercetin and isodulcite when decomposed by means of dilute sulphuric acid.—*Ber. Berl. Chem Ges.*, xv, 214, Feb., 1882. G. F. B.

10. *Maximum of magnetization of diamagnetic and weakly paramagnetic bodies.*—The researches of Hankel, Rowland and others have shown that iron, cobalt and nickel have a maximum point of magnetization. Silow has also maintained that a solution of chloride of iron possesses a maximum point. H. W. Eaton, in this paper discusses the various results of different observers: concludes that a solution of chloride of iron does not possess a maximum of magnetization, but increases in permeability in proportion to the strength of magnetic field (he used from 1 to 7 Bunsen cells), and doubts whether the use of 30 Bunsen cells would show a maximum. Shumeister investigated the maximum conditions of water, alcohol, sulphide of carbon, ether, oxygen and nitrogen, and discovered apparently a maximum. Eaton repeats Shumeister's observations and maintains that this maximum condition does not exist in ordinary magnetic fields. Then follows a comparison of the observations of different observers which discloses great want of agreement. This discrepancy extends also to the various determinations of the diamagnetic constant of bismuth. The following table of the results of various observers is given:

		10^6 k.
1.	Weber (through magnetic influence)	−2·304
2.	" (through electrical influence)	−2·122
3.	Christie	−1·485
4.	Toepler and Ettingshausen	−1·492
5.	Rowland and Jacques (in C. G. S. units), K′	−0·012554
	K″	−0·14324

K′ principal axis of crystal vertical.
K″ " " " horizontal.

—*Ann. der Physik und Chemie*, No. 2, 1882, pp. 225–246. J. T.

11. *Reflection of electrical rays.*—W. Hittorf has maintained that the rectilinear electrical rays proceeding from the kathode in a Geissler tube end when they infringe upon an immovable wall or barrier and are not reflected. E. Goldstein describes what he thinks is an *Experimentum Crucis*, and concludes that a bundle of kathode rays do not end but can excite phosphorescence by reflection from a solid partition or wall. Every surface in suitable condition can serve as a reflector—it matters not whether it is a phosphorescence exciter, an insulator, or a conductor. The

reflected rays can excite phosphorescence and are acted upon by a magnet like the original kathode rays.— *Ann. der Physik und Chemie*, No. 2, 1882, pp. 246–254. J. T.

12. *Influence of mechanical hardening upon the magnetic properties of steel and iron.*—Many investigations upon the relation between the molecular conditions of iron and steel produced by heat, by torsion and by annealing processes, and the resulting changes in magnetic conditions have been made. It appears from the paper of Louis M. Cheesman that the effect of mechanical hardening has not been properly investigated, and this paper contains the results of his investigation upon this point. The method of research consisted simply in determining the magnetic moment of the magnetic bar after it had been subjected to well devised mechanical pressures. The result of his investigations is summed up as follows: Iron in a mechanically hard condition can receive more permanent magnetism than in a soft condition. The magnetic moment of a steel magnet in a mechanically hard condition is greater or smaller than in a soft condition, according as the ratio of its diameter to its length is less or greater than a certain limit.—*Ann. der Physik und Chemie*, No. 2, 1882, pp. 204–225. J. T.

13. *Storage of Electricity.*—A commission consisting of Mm. Allard, L. LeBlanc, Joubert, Potier and Tresca, experimented upon Faure's battery in Paris, January, 1882. The Faure battery was composed of 35 elements, the lead plates of spiral form weighing each, with included liquid, $43{\cdot}700^{kg}$. The lead electrodes were covered with minium to the amount of 10^{kg} per square meter. The liquid consisted of distilled water with the addition of one-tenth of its weight of pure sulphuric acid. The charging machine was of the Siemens type the armature having a resistance of 0·27 ohms, and the inductor 19·45 ohms. The current of discharge was passed through a series of Maxim's incandescent lamps. The authors state, in general, that they obtained the light of one carcel with an expenditure of $5{\cdot}80^{kgm}$ of electrical work per second. They were also led to the conclusion that it is advantageous to charge the battery with the feeblest current possible and to prolong the duration of the charge. The results of the investigation are summed up as follows: The charge of the battery demanded a total mechanical work equivalent to 1·558-horse power during $22^h\ 45^m$, or 1-horse power during $35^h\ 26^m$. The battery received in reality only 0·66 of this work, the rest having been dissipated in the work of excitation.

The exterior electrical work during the entire duration of the discharge amounted to 3809000^{k-m}; the mechanical work consumed was 9570000^{k-m}, but of this amount furnished only 6382000^{k-m} was retained by the battery. Hence the amount recovered during the discharge was 0·40 of the total work, and 0·60 of the stored-up work. The employment therefore of the accumulator has cost 0·40 of the work furnished by the dynamo-electric machine which might have been utilized in other ways. The

advantages of having a reservoir of electricity, however, compensates for this loss of energy.—*Comptes Rendus*, March 6, 1882, pp. 600–604. J. T.

14. *Storage of Electricity.*—Professor Ayrton, F.R.S., delivered a lecture on the storage of energy at the London Institution, March 2, in which he maintains, allowing for the unnecessary waste due to the too hurried charging and too hurried discharging of a Faure accumulator, "that for a million foot-pounds of stored energy discharged with a mean current of 17 ampères, the loss in charging and discharging combined need not exceed 18 per cent," and in some cases he has found it not to exceed 10 per cent. He has found from experiment that 81 pounds of lead and red lead charged and discharged, the discharge lasting eighteen hours—six hours on three successive days—represented in its discharge 1,440,000 foot pounds of work, or 1-horse power for three-quarters of an hour.

The resuscitating power of the Faure accumulator was wonderful. After the eighteen hours of discharge just referred to it was found after a few hours of insulation that the accumulator could give a current of over 50 ampères. The phenomenon resembles the invigorating action of sleep.—*Nature*, March 23, 1882. J. T.

15. *Velocity of Sound in Wood*; by Dr. H. Kayser. (Communicated).—In this Journal for February, 1879, Dr. Magnus C. Ihlseng has published a method of determining the velocity of sound in wood. I take this opportunity of making some remarks in regard to it, although at a somewhat late date. Mr. Ihlseng defines the velocity of sound in wood in two ways: in the first, the rod of wood is fixed in the middle, one end is rubbed and the other end marks its vibrations on a blackened glass plate; by this means are found the number of vibrations n, and half the wave length in wood, $\frac{\lambda}{2}$, equal to the length of the rod; then the velocity is $v = n\lambda$. The number of vibrations can also be found by Kundt's method, the end of the rod causing the air in a tube to vibrate; if $\frac{l}{2}$ designates half the wave length of air in the tube, a the velocity of sound in the tube, then $n = \frac{a}{l}$, and therefore $v = \frac{a\lambda}{l}$.

Mr. Ihlseng obtained in every case greater velocities by the second method than by the first, and was unable to find the reason for the difference. I think the explanation is easily given, and it is this which induces me to send this note. Unfortunately Mr. Ihlseng gives the results of his researches so very incompletely, that I cannot be sure that my supposition is right; but from the words of the author, I must presume, that calculating by the second method, he has taken for a the velocity of sound in free air, that is to say about $332{\cdot}5\frac{m}{\text{sec.}}$. This would be allowa-

ble only if his tube were ∞ wide, or the pitch ∞ high. If this is not the case there is a diminution of the velocity by friction and by conduction of heat, which diminution is to be calculated according to Kirchhoff* by the equation

$$u-a=\frac{\mu\gamma}{2r\sqrt{\pi n}}$$

where u means the velocity in free air, a the velocity in the tube, n the pitch of the tune, $2r$ the diameter of the tube, and γ a constant. This equation I have verified† by experiments and have determined the constant γ to be for glass tubes

$$\gamma=0{\cdot}0235\frac{m}{\text{sec.}}$$

On a later occasion‡ this number was again confirmed.

We shall see what numbers would have been obtained by Mr. Ihlseng with the second method, had he kept in view this equation. He indicates the diameter to be $2r=0{\cdot}019m$; the pitch n can be calculated nearly by his Table IV. I find by it numbers lying between 1000 and 2000; taking as average 1500 vibrations, we find

$$u-a=6m \text{ and } a=326{\cdot}5m.$$

Mr. Ihlseng having, therefore, calculated the velocity of wood by means of the dust figures by $v=\frac{332{\cdot}5\lambda}{l}$, the right equation would have been $v=326{\cdot}5\frac{\lambda}{l}$.

It follows, that for the mean velocity of $4000\frac{m}{\text{sec.}}$ in wood, the number calculated by Kundt's method is too great by $73m$. The mean difference between the numbers found by the two methods, according to Mr. Ihlseng is $61m$,—surely a sufficient agreement, considering that the probable error of his determination reaches $10m$.

Finally I remark, that according to my experiments on glass tubes, the graphic method is quite unfit for precise determinations, because, as Mr. Ihlseng also finds, the rod vibrates not only longitudinally, but at the same time transversely, and therefore the number of vibrations can be determined only very inexactly by the curves.

Berlin Physical. Institut., March, 1882.

16. *The Chemistry of Cooking and Cleaning, a Manual for Housekeepers*; by Ellen H. Richards. 90 pp. 12mo. Boston, 1882 (Estes and Lauriat).—The practical applications of chemical principles to some of the familiar processes of every-day household life have never been better presented than in this little book by Mrs. Richards. Clear and concise in style, and happy in its illus-

* Kirchhoff. Pogg. Ann., cxxxvii. p. 177. † Kayser. Wied. Ann., ii. p. 218.
‡ Kayser, Wied. Ann., viii, p. 444.

trations, it is a successful combination of good science with sound practical advice. It is to be hoped that the day is not far distant when every housekeeper will have the knowledge to understand these principles and the wisdom to apply them in all the homely operations which she has to direct or perform. This little book cannot fail to do good service in bringing about this desired end.

II. Geology and Natural History.

1. *Bulletin of the Illinois State Museum of Natural History* (at Springfield, Ill.). No. 1. Feb., 1882. 44 pp. 8vo. Printed for the Museum, 1882.—This first Bulletin of the Illinois State Museum contains three articles, (1) Descriptions of 54 new species from the Lower Carboniferous limestones and Coal Measures of Illinois and Iowa, and (2) Corrections and proposed new names for species previously described in the Geological Survey of Illinois under names that were preoccupied, and Descriptions of two new species of fossil shells from the Coal Measures of Illinois and Kansas, by A. H. Worthen, State Geologist, and (3) Descriptions of two new species of Crinoids from the Chester limestone and Coal Measures of Illinois, by Charles Wachsmuth. Mr. Worthen announces that all the new species described by him will be fully illustrated in the *Seventh* volume of the Geological Survey of Illinois, now in course of preparation. A large part of them are represented by specimens of unusual perfection partly in the State Collection, but largely in that of Mr. L. A. Cox, of Keokuk, Iowa. The changes of names of species in the published volume of the Illinois Geological Survey, given in the second paper by Mr. Worthen are the following: *Platyostoma Grayvillensis* in place of *P. tumida*, vol. ii; *Modiolopsis rectiformis* for *M. orthonota*, vol. iii; *Mod. Carrollensis* for *M. subnasuta*, vol. iii; *Platyceras subsinuosa* for *Pl. subundatum*, vol. iii; *Pleurotomaria coniformis* for *Pl. conoideus*, vol. v; *Orthoceras Randolphensis* for *O. annulo-costatum*, vol. vi. *L. Lithophaga*, in vol. iii, p. 536. is here named *L. Illinoiensis*.

2. *Glacial-era Climate.*—M. Woeikof, in a paper on "Gletscher und Eiszeiten in ihrem Verhältnisse zum Klima," rejects the idea that an epoch of maximum eccentricity with aphelion in the winter would be favorable for a glacial era. He observes that in the interior of Asia, for example, the greater cold in winter would not favor a large accumulation of snow, while the excessive heat of the summer would produce the melting of the snows to a greater height than now. In the region of the monsoons, the cold and dry monsoons of the winter would have greater force than at present and be less snow-producing; while the great heat of summer would produce increased rains and melting to a higher level. The surface of the ocean would not be of a lower temperature than now, and hence there would be no increased fall of snow over the lands adjoining. The effects from maximum eccentricity

and the earth in aphelion would in any case be slight, and rather unfavorable than favorable to the production of a glacial era.

3. *Post-Glacial Flood.*—An article by H. H. Howorth, on the "Great Post-Glacial Flood," attributing to it the formation of the löss besides other deposits, is contained in the Geological Magazine, numbers for January and February, 1882.

4. *Quincy Syenite.*— Mr. M. E. Wadsworth, in the Proceedings of the Boston Society of Natural History, vol. xxi, Oct. 19, 1881, describes the junction of the Paradoxides slate of Quincy with the syenite of the region, and concludes that the latter is eruptive and therefore of subsequent age to the slate—"late Primordial or more recent." The syenite is stated to be at the junction a "spherulitic quartz porphyry."

5. *An old chapter of the Geological Record, with a new interpretation: or Rock-metamorphism and its resultant imitations of organisms; with an introduction giving an Annotated History of the controversy on the so-called "Eozoon Canadense;"* by Professor W. King and T. H. Rowney. 142 pp. 8vo, with 8 colored plates. London, 1881. (John Van Voorst.) —The authors have here given a catalogue of all papers on the Eozoon with critical notes, and a full statement of their own views on the subject of a branch of metamorphism with which the origin of the supposed fossil is associated.

6. *Species of Eurypterus and Pterygotus from the Water-lime group near Buffalo.*—Mr. Julius Pohlman describes and figures the following as new species of these genera in the Bull. Buffalo Soc. Nat. Sci., vol. iv, No. 2, 1882: *Eurypterus giganteus, Pterygotus globicaudatus, Pt. acuticaudatus, Pt. quadricaudatus, Pt. Buffaloensis.*

7. *Chatauqua Scientific Diagrams, Series No.* 1. *Geology: and First Lessons in Geology;* by A. S. Packard, Jr. 128 pp. 8vo, to accompany the diagrams. Providence, R. I., 1882 (Providence Lithograph Co.)—The geological diagrams, ten in number, are very large lithographic plates, coarse in style of execution, for use in the illustration of lectures or first lessons in geology. They contain restorations of some of the species of the several geological ages, and illustrations also of scenery and volcanic and glacial phenomena. They might be much better. Professor Packard's work treats briefly and in a popular way of the topics illustrated, the action of water and heat, and the succession of life on the globe, with special reference to North America.

8. *Tables for the Determination, Description and Classification of Minerals;* by James C. Foye. 85 pp. 12mo. Chicago, 1882 (Jansen, McClurg & Co.).—A second edition of Professor Foye's useful tables for the determination of minerals has been recently published; it contains some additional tables which will increase its value.

9. *On the Female Flowers of the Coniferæ.*—Under this heading Professor Eichler of Berlin gives his latest views about this important subject in the Monatsberichte der K. Acad. der Wiss.,

Berlin, 1881. He takes it for granted that the morphologists of the present day are agreed that the male *flowers* are the aggregate of stamens which were formerly (and still by Parlatore in DeC. Prodromus) considered an ament, i. e. an inflorescence. He now tries to prove that what we call the female ament is perfectly conformed and corresponding in every respect to the male flower in position as well as in structure, and thus is also a single flower and not an inflorescence.

The simplicity of such an arrangement, the uniformity in the structure of the male and female organs thus established, are certainly seductive, and in the author's opinion the difficulties in his way are readily enough removed. The principal difficulty is found in the presence of two foliaceous organs in the female flower, one, now called the ovule-bearing or carpellary scale, inside of another, the bract, while the male flower consists of a number of simple pollen-bearing bracts (the stamens) arranged around the axis. Now, according to Professor Eichler's view, the carpellary scale is not a distinct organ, but really only an appendage, a ventral excrescence, a ligule, if it may be called so, of a leaf (the bract), born from it and belonging to it; he therefore recognizes only one organ, the bract, and the so-called carpellary scale as its appendage—a view already indicated by Sachs. He reviews and controverts the views of preceding morphologists. Robert Brown declared the carpellary scale to be a leaf in the axil of the bract; but this is a morphological impossibility. Schleiden and Strasburger took it for a flattened axis; but the arrangement of the bundles of vessels makes that untenable. Van Tieghem thought it was a leaf median on an undeveloped axillary bud, but Coniferæ never do produce such median leaves. A. Braun, and after him Caspary, were the first to recognize in the scale a compound organ, consisting of two lateral leaves of such an undeveloped bud, connate on their lower side; Oersted, and more decidedly Mohl, showed that these two leaves were connate with their posterior edges, turning their backs toward the main axis, and Mohl happily compared the scale thus constituted with the double leaf of Sciadopitys; this, however, seems impossible to Professor Eichler, because nothing is *seen* of such an assumed undeveloped axillary bud, and because the distribution of the vessels in the scale does not indicate a double origin, as it does distinctly in the Sciadopitys leaf.

Professor Eichler insists that the carpellary scale of Coniferæ, though often apparently separated from the bract, is really not a distinct organ, but, as stated above, a ligular appendage of the upper face of the bract. He shows that in such appendages the vascular bundles are always arranged in a system opposite to that of the leaf from which they originate; if they spring from the upper side of the leaf, this upper side is turned toward the upper side of the leaf, and if they come from the dorsal side, their dorsal side is turned toward the back of the leaf, and in either case the arrangement of the vascular elements is reversed. In every

leaf the xylem (wood-cells) occupies the upper or ventral side of the vascular bundle, and the phloëm (formerly bast or soft bast-cells) lies below it or toward the dorsal side of the leaf. This is so in the coniferous leaf as in all others, and in the bract, while the ligule or carpellary scale shows the arrangement reversed, a well established fact. This carpellary scale wherever it exists (principally in Abietineæ) bears on its back one or several ovules. In Araucaria it is a small process, of ligular form, from the middle of the leaf-bract, with one ovule; in Cunninghamia it is a narrow transverse crest with three ovules; in Cryptomeria it is a jagged crest, at last much larger than the bract itself; but in Damara no trace of an appendage can be found. The same is the case with most Taxodineæ, where only a certain thickening of the bract is noticeable. But in Abietineæ we see two apparently distinct organs; examining them, however, more closely, we find them always cohering at base, and where they at maturity separate from the axis as in Abies and Cedrus, they fall off together, as they should do, where one is only an appendage of the other. In Cupressineæ no carpel-bearing appendage at all is observed, and the ovules are as nearly axillary as possible, or, where there are many, they seem to spring partly from the base of the bract and partly from the axis itself; but the thickened upper side of the scale shows also a reversed arrangement of the vessels, "as it can not be otherwise, where the leaf is so thickened on the inner side that at last it even becomes peltate." The other Coniferæ follow the same rule, the ovules stand in the axil of the bract; but in Taxineæ they are terminal products, surrounded by the uppermost leaves or bracts.

The proliferation sometimes observed in the female flowers of Abietineæ has been thought to furnish proof for the axillary nature and distinctness of the carpel; but Professor Eichler is satisfied that the abnormally developed branchlet is not the development of a supposed carpellary axis, but a really new axillary production of the bract therefore between the carpellary appendage and the main axis, and that the division of the carpel into two pieces, often noticed in such monstrosities, is produced by pressure only.

Eichler then compares the ovule of the Coniferæ to the sporangium of allied vascular cryptogams, and finds in Isoetes the sporangium on the base of the leaf where also a ligula is present, in Lycopodium in the axils, and in Psilotum at the end of branchlets. The essential character of gymnospermy, however, he finds not as much in the open carpel, which also occurs in some higher organized plants, as in the absence of a stigma and in the immediate action of the pollen on the ovule.

In a second paper, "*Ueber Bildungsabweichungen bei Fichtenzapfen*" (Sitzungsb. d. K. Ac. Wiss., Berlin, 1882), Professor Eichler gives us a careful analysis of monstrosities observed on the Norway Spruce, and of one on the Himalaya Hemlock, and tries to show how former interpreters had misunderstood their teaching, and how these examples fully confirm his own views,

expressed in the foregoing paper. He has procured the very specimens which Stenzel, Willkomm, Oersted and Parlatore had examined, analyzed them with great care, and gives figures and sections of the principal forms found. He demonstrates that the so-called fruit scale in those monstrous cones is not divided into two lateral leaves, but becomes irregularly toothed, folded or lobed, sometimes simulating two or more leaves, and finally develops a knob and at last a bud, which may and does sometimes grow out into a branch, always on the inside of and adnate to the metamorphosed scale, i. e. on the side towards the axis of the cone, often enveloped by its folds, but never between it and the bract, which ought to be the case if the now prevailing view of the nature of the scale (as formed by two lateral leaves connate on their axial side) were true.

Unfortunately he has not had occasion to examine such monstrosities where these two leaves are foliaceous, partly or entirely distinct, originating not from the base but from the very axil of the bract, and not divided by any possible pressure, such as occur at the base, not at the top, of proliferous cones of *Tsuga Canadensis*. In such cones the transformation progresses from a pair of separate leaves in the axil of a leaf-like bract to the partly united, then to the small and notched scale, at last to the large ovuliferous scale in the axil of a small retuse bract.

It may be stated in passing, that the first lateral bracts at the base of a shoot, in pines at least, are *not* inclined outward or toward the supporting bract, but rather decidedly inward, toward the axis, and are overlapping on the inner and upper side of the shoot, leaf-bundle, or flower.

Professor Eichler has given us a very valuable contribution towards the solution of the interesting question he treats of; but he has not yet settled it, and it will continue to tax the ingenuity of morphologists.

G. ENGELMANN.

10. *Domestication of Wild Ducks.* (Bulletin of the Buffalo Society of Natural Sciences, vol. iv, No. 2.)—In a paper "on the domestication of some of our Wild Ducks," Mr. Charles Linden, the author, states after efforts to domesticate several of the species, capturing them young or raising them from eggs, that none of those transferred to the barn-yard "adapted themselves thoroughly to this state excepting the Mallard, Dusky Duck and Canada Goose, the progeny of which prospered well and attained a greater weight and size than the ordinary domesticated stock. Some of them are still living and betray in many instances a tendency to revert in point of plumage to their original condition, while the majority have become completely metamorphosed into ordinary barn-yard fowl. No hybrids from any two different wild species, which bred only within the enclosure, were ever obtained excepting from crosses between the Mallard and Dusky Duck." The crossing was readily accomplished "without any need of resorting to special inducements." He says, "it is evident that the Dusky Duck is fully as domesticable as the Mallard

which has been thus far supposed to be the originator of our common tamed ducks."

11. *Conchologische Mittheilungen, als Fortsetzung den Novitates Conchologicæ, herausgegeben von* Dr. E. von MARTENS, Professor in Berlin. Band I. 104 pp. 8vo, with 18 colored plates. Kassel, Germany, 1881. (Theodor Fischer.)—The plates illustrate species (with their varieties) of the genera *Nanina*, *Helix*, *Bulimus*, *Pleurotomaria*, *Pleurotoma*, *Bucainum*, *Pupa*, *Helicarion*, *Limnæa*, *Tornatellina*, *Stenogyra*, and *Partula*.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

First Annual Report of the Bureau of Ethnology, to the Secretary of the Smithsonian Institution 1879–'80; by J. W. POWELL, Director. 604 pp. Roy. 8vo, with many plates and wood-cut illustrations. Washington, 1881.—After a prefatory statement, by the Director, of the work now in progress, under the auspices of the Ethnological Bureau, by a number of special investigators, this volume presents a series of very valuable papers pertaining chiefly to the North American Indians. The subjects of Mr. Powell's own reports are (1) the Evolution of language, (2) sketch of the Mythology of the North American Indians, (3) Wyandot government, (4) on Limitations to the use of some anthropologic data. These are followed by other reports as follows: a further contribution to the study of the Mortuary customs of the North American Indians, by H. C. YARROW; Studies in Central American Picture writing, by E. S. HOLDEN; Cessions of land by Indian tribes to the United States, by C. C. ROYCE; Sign language among North American Indians, by Col. GARRICK MALLERY; Catalogue of linguistic manuscripts in the library of the Bureau of Ethnology, by J. C. PILLING; Illustrations of the method of recording Indian languages, from the MSS. of J. O. DORSEY, A. S. GATSCHET and S. R. RIGGS. The numerous illustrations of the volume are highly instructive as to Indian rites, modes of life, hyeroglyphics, and sign language. and other topics discussed.

OBITUARY.

CHARLES ROBERT DARWIN, whose "Origin of Species" caused a change in the world's thought almost as abrupt as a turn in the tide, and whose later works have successively led the way into new fields of research, died on Wednesday, the 19th of April. Darwin was born on the 12th of February, 1809.

E. DESOR, of Neufchatel, Switzerland, died early in March. Mr. Desor was with Agassiz in his investigations of the Alpine glaciers, and later published an independent volume on the subject. He was the author also of various geological and paleontological memoirs. His property he bequeathed to the city of Neufchatel for scientific purposes.

Bulletin of the Museum of Comparative Zoology at Harvard College. Vol. IX. No. 1. "Description Sommaire des espèces nouvelles d'Astéries," by Edmond Perrier, Prof. Jardin des Plantes de Paris: being one of the Reports of the results of dredging under the supervision of Alexander Agassiz, in the Gulf of Mexico, 1877–78, by the United States Coast Survey Steamer "Blake." 32 pp., 8vo. Cambridge, 1881.

THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

Art. XLIX.—*Respiration of Plants;* by W. P. Wilson, S.D.

The process of breathing in animals and plants is essentially the same. In both the free oxygen from the air, or surrounding medium, is carried into the living tissues, where, after a series of chemical changes, carbonic acid, water and perhaps some minor compounds are evolved as excretory products.

The changes in the living cell, alike in animals and plants, determine the amount of oxygen taken up and the products given off. In both an increase of temperature is a direct effect of respiration.

In this process of respiration, for plants as well as animals, a certain amount of absolutely necessary force is secured for supplying the life-functions of the organism. If either the living animal- or plant-cell be deprived of oxygen for any considerable length of time the life activities cease, and, later, death ensues. This oxygen-respiration is then a constant need of the living cell, whether it be of plant or animal.

When plants possessing chlorophyll are exposed to the sunlight they carry on a process of assimilation, in which organic substance is produced from carbonic acid and water, and oxygen set free. The amount of carbonic acid decomposed and of oxygen given off, in this preparation of organic food for the plant, far exceeds, as a rule, the carbonic acid excreted and the oxygen taken up in respiration. Thus it happens that the process of respiration, in plants containing chlorophyll and exposed to the light, is a hidden one, and difficult of demonstration.

When plants are deprived of every trace of free oxygen by placing them in an atmosphere of nitrogen or of hydrogen, they still continue, so long as life exists, to excrete carbonic acid. The discovery of this fact, which has been observed for animals as well as plants, is not of recent date, although its signification was only recently understood. As early as 1798 Rollo* observed that barley, which had been wet for two days and then placed in a vacuum, excreted carbonic acid; and that at the end of twelve days, the amount equaled six times the volume of the barley.

Saussure† placed plants in an atmosphere of nitrogen to see if they would grow, and found that they excreted carbonic acid, which he remarks must have been produced at the expense of the substance of the plants.

At a still later date Bérard,‡ while experimenting on the preservation of fruits, placed green pears in a vacuum and observed for several days following an excretion of carbonic acid.

Broughton§ and also W. Pfeffer‖ have recorded the same phenomenon in plants deprived of free oxygen.

In 1875, Pflüger¶ obtained some very interesting results in animal respiration while experimenting on frogs. These animals, placed in an atmosphere of nitrogen, were found during the first five hours and a half to expire nearly the same amount of carbonic acid as if they had been placed in pure oxygen. In another of Pflüger's experiments, a frog continued to give off carbonic acid during eleven consecutive hours, and at the end of that time had apparently lost none of its normal powers. Pflüger showed that these chemical activities, which result in the expiration of carbonic acid in the absence of free oxygen, take place in the cells. He named the process *intramolecular respiration*.

In 1878 a critical résumé on the nature and signification of respiration in plants,** written by W. Pfeffer, brought together all the then known facts which could be made to bear on this subject. The similarity existing between animal and plant respiration was sharply noted, and the term *intramolecular respiration*, taken from Pflüger, was made to cover a like series of phenomena in plant life, viz: the chemical changes continu-

* Annales de Chimie, 1798, vol. xxv, p. 42.

† Recherches Chimiques, 1804. p. 201.

‡ Annal. de Chimie et de Physique, vol. xvi, 1821, p. 174.

§ Bot. Zeit. 1870. p. 647.

‖ Arbeit. d. Würzburger Instituts, 1871, Bd. I, p. 34.

¶ Archiv. für Physiologie. Bd. X. 1875. p. 313. Pflüger gives other references to investigators in animal physiology who had made similar experiments on frogs. dating back into the 18th century.

** Das Wesen und die Bedeutung der Athmung in der Pflanze. Landwirthschaftliche Jahrbücher. 1878, Bd. VII, p. 805.

ing to take place in the plant-cell after oxygen has been withdrawn, resulting always in the production of carbonic acid, and often in other more or less important products. In this article the author lays great stress on *intramolecular respiration* as being the *first cause* of the *oxygen* or *normal* respiration.

One of the next works of any special importance on plant respiration appeared in 1879.* Wortmann measured and compared the carbonic acid expired from germinating plants placed in common air, with that given off from an equal number of plants placed in a vacuum.

He states that for short periods of time (from one to three hours), the presence or absence of free oxygen makes absolutely no difference in the amount of excreted carbonic acid gas. On the basis of these results he proposed a new theory, viz: that all the carbonic acid produced in plant respiration has its origin in intramolecular decompositions; or, in other words, that the free oxygen of the air takes no direct part in the formation of the carbonic acid in respiration.

The following paragraphs consider briefly one phase of intramolecular respiration and give in very condensed abstract a series of experiments which will later be published in full.†

The main question, here discussed, is whether the carbonic acid excreted in plant-respiration *is or is not a partial product of direct oxidation from the free oxygen of the air.*

To decide this question, quantitative measurements were made of the expired carbonic acid from the same plants placed both in air and in hydrogen gas. The methods of experimentation used were the following: a constant current of air, previously freed from carbonic acid, was passed by means of an aspirator, first through a large number of germinating seeds, or other objects to be experimented upon, and then through long tubes filled with barium hydrate in which the carbonic acid given off by the seedlings was absorbed, essentially in accordance with Pettenkofer's method.‡ After a given time had elapsed, hydrogen, as an indifferent gas, was used to replace the air. This was quickly done by exhausting the air in the seed-vessel and tubes leading thereto, and then introducing hydrogen to take its place. A constant current of hydrogen was then passed over the seedlings, precisely as had been done previously with air.

The carbonic acid was determined for either half hourly or hourly intervals. This was easily accomplished by using two

* Wortmann. über die Beziehungen der intramolecularen zur normalen Athmung der Pflanze. in Arbeit d. Würzburg Instituts, 1880, Bd. II, p. 500.

† A much shorter abstract than the present appeared in German in "Flora," No. 6, 1882.

‡ Abhandlungen der Akademie d. Wissenschaften in München. Cl. II. Bd. IX. Abth. II, p. 229.

absorption tubes filled with barium hydrate, and so connected together by glass stopcocks that the current of air or gas, when passing through one tube, could be instantly turned through the other without interruption. Thus while the current passed through one tube, the other could be removed, emptied, refilled and replaced for the next half hour's determination.

In conducting an experiment, measurements were made first in air for several half hours, then the air was replaced by hydrogen, and after an equal number of half hours, for hydrogen was again substituted air, in which the third series of determinations took place. The last series in air was used to compare with the first, and it readily showed whether the seedlings had undergone any lasting change for want of oxygen. The temperature of the plants for any given experiment was not allowed to vary; also the current of air or gas was held constant for all the successive half hours.

A great advantage in the methods here adopted lay in subjecting the same seedlings, first to air, and then to hydrogen; thus the products of the respiration of the same plants under these two different conditions could be compared.*

A large number of seedlings were employed (from one to several hundred, according to size), thus ensuring the production of a comparatively large amount of carbonic acid in a short space of time, with which much more accurate measurements could be made than with small quantities. The amount of carbonic acid was determined by the volumetric method.

According to the investigations of Wortmann with seedlings of *Vicia Faba*, *Phaseolus multiflorus* and some others, the carbonic acid excreted in short spaces of time, one to three hours, was found to be the same whether oxygen was present or not.†

In the case of seedlings of *Vicia Faba*, with which Wortmann mostly experimented, I have found this to be substantially true; for all other germinating plants, flowers, or parts of plants there was an immediate decrease in the carbonic acid produced when oxygen was excluded. The first half hour's respiration in hydrogen often yielded but one third or even one-fourth the carbonic acid produced by the preceding half hour's respiration in air. After three or four consecutive half hours of intramolecular respiration, sometimes from the very first, a steady decrease in the carbonic acid was recorded for every following half hour. This was also found to be true for *Vicia Faba*. The following are the results obtained from

* Wortmann used two sets of plants, as nearly alike as selection would permit, one in vacuum compared with one in air.

† "Als ich jedoch die in ganz kurzen Zeiträumen—nach der ersten, zweiten und dritten Stunde—ausgeschiedenen Kohlensäuremengen mit einander verglich, so fand ich jedesmal, 'dass das in dieser Zeit durch intramoleculare Athmung ausgeschiedene Kohlensäurevolumen dem durch normale Athmung erzeugten gleich ist.'" Wortmann, l. c., p. 509.

Lupinus luteus.

I. Period.	Air.	1st half hour,	5·7 mgms.	CO_2.
		2d half hour,	6·6 "	"
II. Period.	Hydrogen.	3d half hour,	1·5 "	"
		4th half hour,	1·5 "	"
III. Period.	Air.	5th half hour,	3·9 "	"
		6th half hour,	5·7 "	"

The comparative decrease in the amount of expired carbonic acid in hydrogen is here greater than with many plants. The following fungus shows much less difference:

Cantharellus cibarius.

I. Period.	Air.	1 hour	=16·20 mgms.	CO_2.
II. Period.	Hydrogen.	½ hour=5·28 / ½ hour=5·52	=10·80 "	"
III. Period.	Air.	1 hour	=16·20 "	"

It will be seen that with *Lupinus luteus* less carbonic acid was measured in the fifth than in the sixth half hour. This is partially based upon the fact that at the beginning of the fifth half hour the seed-vessels contained less carbonic acid than at the beginning of the sixth. With a constant current of air and a constant production of carbonic acid, it requires a little time after the air or gas has been changed before an equilibrium between the produced and the out-flowing gas establishes itself.

Among a large variety of germinating plants, branches with leaves, flowers, fruits and fungi, *Vicia Faba* has been the only plant which has given results differing from the above.

That the volume of carbonic acid expired in normal and in intramolecular respiration is the same, is, therefore, in accordance with the facts above stated, untrue. The theory which Wortmann founded upon this fallacy, viz: that the total volume of carbonic acid excreted in plant-respiration has its origin absolutely independent of the oxygen of the air, in intramolecular decompositions, falls also to the ground.

Moreover, if it had been found by experiment, that the volume of carbonic acid given off in intramolecular equaled that of normal respiration, Wortmann's theory would still fail.

This has been well shown by W. Pfeffer, in saying, substantially: if an equal amount of carbonic acid were formed in both intramolecular and normal respiration this would only prove that the same number of carbon affinities for oxygen had been satisfied in each case, would in no way indicate from whence the supply of oxygen came. And in case free oxygen was active in normal respiration, still in intramolecular, when free oxygen was absent, the full supply might yet be obtained through constant powerful attractive forces which could take

oxygen from other combinations, and in this way give rise to secondary changes.*

Partial presence of Oxygen.—When seedlings of *Helianthus annuus* are placed in a current of common air for a given period of time, and then for the same length of time are exposed to a current of air made up of a mixture of one-fifth air and fourth fifths hydrogen, a comparison of the excreted carbonic acid in both cases shows no difference whatever. Sufficient oxygen is present in the mixture to supply all demands made by the plants. When, however, the expired carbonic acid in the respiration of plants, placed first in air, and then in a mixture of $\frac{1}{20}$ air and $\frac{19}{20}$ hydrogen, is compared, one finds the amount much greater during respiration in air. Thus a trifle over one per cent of oxygen in the air is not sufficient to supply the demands for this gas made by such seedlings.

Influence of light on respiration.—The presence of light does not in any appreciable degree directly affect the amount of carbonic acid given off in the respiration of plants. I have experimented on Orobanche, Monotropa, Fungi and seedlings of several kinds. Neither in air nor in hydrogen gas, for plants placed in the light or in the dark, is there any difference in the excreted carbonic acid which can be measured.†

Tübingen, Würtemberg, April, 1882.

ART. L.—*On the Question of Electrification by Evaporation;* by S. H. FREEMAN, Fellow in Physics in Johns Hopkins University, Baltimore, Md.

IT has been very commonly believed that evaporation is an important source of atmospheric electricity. So far as this belief has an experimental basis, it is to be found in the researches of Pouillet,‡ and of Tait and Wanklyn.§ In comparison with their work the experiments of Volta, Saussure and others are of little value. As the result of an elaborate series of experiments Pouillet came to the following conclusions:

1. Simple changes of state never give the least sign of electrification.

* Denn daraus folgt nur, dass in beiden Fällen gleichviel Affinitäten des Kohlenstoffs mit Sauerstoff gesättigt werden, nicht woher dieser stammt, und falls der freie Sauerstoff mitwirkte, könnten beim Fehlen dieses die fortdauernden, mächtigen, Anziehungskräfte nunmehr ihre volle Befriedigung finden, indem sie durch Entreissung von Sauerstoff aus anderweitigen Verbindungen eben die Veranlassung zu sekundären Prozessen werden. Pfeffer, Pflanzenphysiologie, Bd. I, 1881, p. 371.

† The methods of analysis which I have used allowed the detection of one-tenth of a milligram of carbonic acid without difficulty.

‡ Annales de Chimie et de Physique, II, tome xxxv, p. 401, and xxxvi, p. 4.

§ Phil. Mag., IV, vol. xxiii, p. 494.

2. From solutions of alkaline solids the water evaporated carries away a negative charge.

3. From solutions of gases, acids or salts the water carries off a positive charge.

Tait and Wanklyn repeated Pouillet's experiments with a much more sensitive electrometer. They detected electrification where Pouillet had failed to do so, e. g., in the evaporation of distilled water; and in some other cases the effects obtained were totally different in kind and degree from those obtained by Pouillet and earlier experimenters.

In these experiments a few drops of liquid were dashed on a red hot platinum dish insulated and connected with an electrometer. So long as the spheroidal state continued, little or no electrification was observed; but as soon as violent vaporization began, decided deflections were obtained. This fact and other circumstances about the experiments indicate that friction was the chief source of electrification and make it doubtful whether evaporation had any part in producing the observed electrification. Tait and Wanklyn recognized the fact that to friction was due a large part of the electrification which they obtained. Still, in his lecture on Thunder Storms,* Professor Tait, speaking of atmospheric electricity, says: "In calm, clear weather the atmospheric charge is usually positive. This is very commonly attributed to evaporation of water, and I see no reason to doubt that the phenomena are closely connected." After reading these lectures the writer of this article decided to investigate whether evaporation alone and under normal conditions causes electrification, and whether such electrification, if any, is sufficient to account for the phenomena of atmospheric electricity. In this connection it will be remembered that Faraday traced the electricity, produced by the escape of steam or water from orifices, to friction, and concluded it was not due to evaporation, nor did it have any bearing on atmospheric electricity.

The investigation was begun with the expectation on the part of the writer of finding electrification. Professor Rowland, to whom the author is much indebted, believed that no electrification would be found. In any case the subject seemed important enough to warrant experiments which were free from the objections which hold against those already described. At the very beginning of the investigation it was found that at most the electrification due to evaporation would be extremely small and very great caution would be necessary to eliminate various sources of error. The apparatus finally used consisted of an evaporating dish 19^{cm} in diameter and 1^{cm} deep, insulated, and connected with one pair of quadrants of a Thomson's quadrant electrometer. The other pair of quadrants and the case of

* Nature, vol. xxii, p. 340.

the electrometer were connected with earth. By means of a mercury commutator the evaporating dish and its connections could also be connected with earth. The evaporating dish was supported on a wire frame suspended by silk threads. To prevent disturbances due to electricity on neighboring objects, particularly the clothes of the observer, it was found necessary to enclose the whole apparatus in a metallic case. Openings were made in this case to facilitate evaporation and to permit the mirror of the electrometer to be seen. The commutator was governed by a silk thread passing through an opening in the case. In the experiments, the results of which are given in table II, the evaporating dish was of copper; in the other cases it was of tin. The liquids examined were alcohol, sulphuric ether, water, and solutions of NaCl and of $CuSO_4$. The last three were most carefully studied, water and NaCl because of their importance in evaporation in nature, and $CuSO_4$ because of the very large deflections which Tait and Wanklyn obtained with it.

The electrometer was about thirteen times as sensitive as Professor Tait's. Its deflections were reduced to absolute measure by comparison with a Daniell's cell, the deflections produced by which were observed before and after each series. The capacity of the evaporating dish and its connections was found by comparison with Professor Rowland's standard condenser to be 65^{cm} nearly. The rate of evaporation was determined by weighing the evaporating dish and liquid before and after each series. It was found impossible to eliminate every source of electricity except evaporation, since deflections were always obtained even with the evaporating dish dry. In order to correct for this each series began and ended with two or more observations of the deflections obtained by insulating for a known time, usually five minutes, the dry evaporating dish. Between these observations several similar observations with the liquid evaporating were made.

As the result of a large number of observations in which the evaporating dish was insulated for five minutes:

Alcohol gave a potential from	−·04 to −·09	that of a Daniell's cell.	
Cotton wet with alcohol gave a potential from	+·02 to −·06	"	"
Sulphuric ether gave a potential from	−·02 to −·10	"	"

(The sign indicates the charge apparently carried away by the vapor.) No correction has been made in the above figures for the deflections obtained with the dry dish. These were more variable, but usually of the same sign, as when a liquid was evaporating, and of a magnitude not very different. Making this necessary correction—

Alcohol gave a potential from	−·024 to −·065	that of a Daniell's cell.	
Cotton wet with alcohol gave pot'l from	−·028 to −·050	"	"
Sulphuric ether gave a potential from	−·004 to −·023	"	"

In the above observations the rate of evaporation was not measured.

The earlier observations on water and salt water gave deflections about 0·1 that given by a Daniell's cell, the deflections with the dry dish being nearly the same (see table I). Though the dish was insulated for five minutes or more, the position of the spot of light was read every 30 seconds. Far the greater part of the deflection was attained in the first minute or two, and after five minutes scarcely any further deflection could be discovered.

The observations thus indicated that the small deflections obtained were mainly due to leakage from electrified parts of the apparatus. The sources of this leakage were carefully investigated and three principal ones were discovered, viz: the charged needle of the electrometer, the vulcanite posts supporting the electrodes of the electrometer, and the glass cup of the commutator. In the later experiments care was taken to eliminate these sources of leakage as far as possible. The connections were so made, that the electrodes and commutator were not touched for days before the experiments, and the charge on the needle was not replenished within about 24 hours of the experiment. When these precautions were taken, the deflections became less than 0·01, and generally less than 0·005 of a Daniell's cell (see table II).

In contrast with these deflections, Tait and Wanklyn obtained by dashing liquids on red hot platinum, for

Solution $CuSO_4$ a potential	+ 300	times	that of a	Daniell's cell.
Solution NaCl a potential	+ 120	"	"	"
Distilled water a potential	+ 24	"	"	"
Alcohol	+ 3	"	"	"

In order to compare the deflections obtained by evaporation with those obtained by friction, the experiments of Tait and Wanklyn were repeated. It was impossible, however, to measure the deflections obtained, since in almost every case, as soon as the spheroidal state ceased, the spot of light went beyond the limits of the scale.

To show the sensitiveness of the apparatus to very slight friction it was so arranged that the drops of liquid could fall upon the evaporating dish from an insulated conductor in metallic connection with it. A few drops of liquid, falling 3 or 4^{cm}, were sufficient to give deflections of nearly the size obtained from a Daniell's cell and much larger than any obtained in evaporation.

In order to compare the results obtained with the phenomena of atmospheric electricity the writer computed the virtual depth of water which would be necessary to produce one flash of lightning, if the vapor in a thunder-cloud had been electrified as indicated by the experiments. By virtual

depth is meant the depth of the layer of water over the whole area of the cloud, were all its vapor condensed to the liquid state.

Let Δ=this depth in c.m. for a cloud of area A and height a.

Let V and C=respectively the potential and capacity of the cloud.

Let q=the charge per gram of water.

Then

$$\Delta=\frac{VC}{Aq}$$

But from Sir Wm. Thomson's experiments $V=130a$,* and by the ordinary formula for a condenser of horizontal plates

$$C=\frac{A}{4\pi a}$$

Now in the experiments,

Let d=the deflection obtained by insulating for t minutes, and apparently due to evaporation.

Let D=the deflection obtained from a Daniell's cell.

Let W=weight in grams of liquid evaporated in T minutes.

Let v and c=potential and capacity of evaporating dish and its connections.

$$\therefore q=\frac{vcT}{tW}$$

But $c=65$ c.m. as stated above; and $v=0{\cdot}00374\frac{d}{D}$ in electrostatic units according to Sir Wm. Thomson's measurements.†

$\therefore \Delta=43\frac{tWD}{Td}$ in terms of the original measurements in the experiments.

I. *Table showing results of earlier series.*

Liquid.	Deflection with evaporation.	Deflection with dry dish.	d in scale divisions.	D in scale divisions.	t in minutes.	T in minutes.	W in grams.	Δ in c.m.	Sign of apparent charge of vapor.
Distilled water	4·12	4·60	+0·48	42·02	5	43	1·44	630	+
Distilled water	4·82	4·33	−0·49	42·05	5	43	0·49	210	−
Distilled water	3·95	4·50	+0·55	41·55	5	37	0·54	237	+
Distilled water	2·48	2·33	−0·15	42·00	5	41	0·80	1170	−
Solution NaCl	6·70‡	4·68	−2·02	41·75	5	55	0·29	24	−
Solution NaCl	3.47	4·40	+0·93	41·50	5	54	0·48	85	+
Solution NaCl	3·10	3·94	+0·84	42·20	5	39	0·70	194	+

* Papers on Electricity and Magnetism, p. 259.

† Papers on Electricity and Magnetism, p. 245.

‡ Throughout this series there was an instantaneous deflection at breaking contact, which was several times larger than the total deflection obtained during the 5 min. insulation. The series therefore is of much less value than any of the others in which the instantaneous deflection was never more than 0·1 of a division.

II. *Table showing results of later series.*

Liquid.	Deflection with evaporation.	Deflection with dry dish.	d in scale divisions.	D in scale divisions.	t in minutes.	T in minutes.	W in grams.	Δ in c.m.	Sign of apparent charge of vapor.
Saturated solution $CuSO_4$	0·3	0·0	+0·3	37·6	2	174	3·19	198	+
"	0·12	0·6	+0·6	37·6	2	174	3·19	99	+
"	0·8	0·6	+0·2	37·6	10	174	3·19	1482	+
"	0·6	0·42	+0·18	39·6	10	38	0·9	2240	+
"	0·5	0·21	+0·29	39·6	5	38	0·9	695	+
"	0·1	0·21	−0·11	39·6	5	38	0·9	1833	−
"	0·3	0·21	+0·09	39.6	5	38	0·9	2240	+
Saturated solution NaCl	0·0	0·35	−0·35	39·6	6	30	0·54	525	−
"	0·2	0·12	+0·08	39 6	2	30	0·54	766	+
"	0·4	0·35	+0·05	39·6	6	30	0·54	3678	+
Hydrant water	1·6	0·6	+1·00	37·6	10	30	0·59	318	+
"	1·45	0·6	+0·85	37·6	10	30	0·59	373	+
"	1·3	0·6	+0·70	37·6	10	30	0·59	454	+
Distilled water	0·5	0·6	−0·10	39·6	7	35	0·89	3031	−
Cotton wet with hydrant water	1·0	0·66	+0·34	37·6	11	30*	0·59*	1029	+

The actual value of Δ (the virtual depth of water) for a cloud 1500 meters thick, if condensation began at 35° C. is about 5·9 c.m.; at 30° C. is about 4·5 c.m.; at 25° C. is about 3·4 c.m.; at 20° C. is about 2·6 c.m.; at 15° C. is about 1·9 c.m.

Hence, even if the deflections d of the tables are really due to evaporation, and if evaporation be the principal source of the atmospheric electricity, the quantity of water, which would be required to produce a single flash of lightning, is very much greater than the actual quantity ever found in a thunder-cloud, while a thunder-cloud usually gives not one but many flashes.

It may be objected to this reasoning that a thunder-cloud in some way collects the electricity obtained by the evaporation of a much larger quantity of water than that contained in itself. On this account it is of interest to consider the total evaporation on the globe. If 100 c.m. be taken as the average annual rainfall for the whole surface of the earth and 400 c.m. be taken as the value of Δ, the total annual evaporation on the earth is sufficient to produce only about 14,000,000 flashes of lightning from clouds nine square kilometers in extent. Hence if one were able to observe every flash of lightning which occurs within eighteen kilometers of himself the average number of lightning flashes seen by such observers at different points of the earth's surface in one year would be only twenty-eight. Calculation from more exact data would give a less

* In this case the rate of evaporation was not measured, but was assumed in computing Δ to be the same as for hydrant water at the same time. The rate was probably greater, which would make Δ still greater.

number. This calculation assumes that all the electricity is discharged through lightning flashes, whereas a very large portion of the atmospheric electricity is discharged in other ways, e. g. in the aurora borealis and other atmospheric phenomena which are referred to electricity and in quiet discharges which take place without any noticeable accompanying phenomena.

Evaporation is then at most a very insignificant source of the atmospheric electricity.

But further, the following facts are to be observed:

1. The deflections obtained in the experiments were always very small. (In the original readings it was easy to make an error of 0·1 a division, and though the numbers in the tables are the means of several observations, they are still affected by this error of reading.)

2. The sign of the apparent charge is not always the same for the same liquid. This is particularly noticeable in the important case of water.

3. The deflections were very much diminished when care was taken to eliminate very small sources of electricity. Still the deflections, obtained with the evaporating dish dry, are usually much larger than the difference between these and the deflections, obtained when a liquid was evaporating.

Evidently then most of the electrification was due to other causes than evaporation, and the experiments do not certainly trace any electricity whatever to this source.

The problem of the source of the electricity of the atmosphere is still unsolved. Evaporation, first proposed by Volta, whose theory until now has been better supported by experiment than any other, fails to account even for a small portion of it; and no other source has been proposed, which can as yet be considered sufficient.

Art. LI.—*Observations on Snow and Ice under pressure at Temperatures below* 32° *F.;* by Edward Hungerford.

The following experiments on the behavior of snow and ice under pressure, were conducted during the successive winters from 1869 to 1871. They have never been given in detail to the public. At the meeting of the American Association for the Advancement of Science, held in Burlington, August, 1867, I gave a résumé of the observations made in the previous winter or spring, under the title of "A Preliminary Notice of Experiments on Snow at Temperatures below 32° F." Of this paper a short abstract appears on page 39 of the proceedings of the Association for that year. I also gave at the Chicago meeting,

of the following year, some account of the work done in the winter preceding. On neither of these occasions were details of observations given to the press. The work was incomplete, and as even at my home in Vermont, the periods of extreme cold, lasting for two or three days, in which the most favorable opportunities are given for conducting such experiments, do not occur many times in any one winter, my work ran along until the spring of 1871. My note-books show an accumulation of numerous trials of the effect of pressure upon snow and ice, only a portion of which will be included in this article.

After the observations were made, a change of residence for a number of years, took me away from Vermont to a region less favorable for such observations. Other occupations have also prevented me from putting the results into presentable shape. In the meantime, however, these results have not, so far as I know, been anticipated, and though they are not by any means as satisfactory as I could wish, the publication of them may at least save anyone else the necessity of going over the same ground. I give first in order a series of experiments with prisms of ice, transversely fractured, and welded again under a relatively light pressure, at various temperatures ranging from 26° F., down to 9° F., and a series of experiments on snow under pressure in an iron press.

A few words as to the object sought in this investigation. In the first place I wished to ascertain whether fractured masses of ice, when brought together at temperatures considerably lower than the ordinary freezing point of water, will be firmly reunited under a moderate or even a heavy pressure. Also, whether cold and dry snow will under like circumstances of pressure become converted into solid ice.

Thirdly, I have considered it desirable to note whether the time element intervenes as a factor, whether reunion and glaciation at low temperatures take place instantaneously, or whether the process requires time for its completion.

And in the fourth place, it is a matter of interest and perhaps of practical bearing on theories of glacier motion, to know whether, in case such union of ice masses and snow granules actually does take place at low temperatures, we are to attribute the mending of the ice joint and the glaciation of the snow to regelation, on the theory advanced originally by Faraday,* or whether the union is a simple result of the plasticity of the ice retained at low temperatures. The supposition of regelation necessarily involves the development of moisture along the ice joint and among the snow granules. In the absence of such moisture the result is to be ascribed simply to the molec-

*The observation was Faraday's, the term regelation was applied to the observed facts by Professor Tyndall.

ular plasticity of ice, whether in the mass or in the form of minute snow crystals. The mention of these points, around which the interest of the investigation gathers, will enable the reader to follow the details more intelligently.

My method of conducting the trials with prisms of ice is as follows: The prisms are obtained by sawing a block of lake ice into slabs an inch or two thick, and again sawing the slabs into prisms three or four inches long. The prisms are then transversely broken. A couple of small, wooden clamps, such as carpenters use, each with two light wooden screws are provided, and the two inner faces of each clamp are lined with emery cloth, to keep the ends of the prisms from slipping when the pressure is brought to bear upon them. In such a clamp, which should be light (made with, perhaps, half inch wooden screws, and the opposing pieces not more than a foot long, by a half inch thick and three inches wide), two prisms can be treated at the same time. The fractured faces of the prism are brought together, and when they have been carefully adjusted, the clamp may be laid over the ends of the two prisms which lie parallel and near to each other on the table. The screws are then gently tightened. To avoid heat and moisture the handling should be done, if they are handled at all, with a cold cloth; or they may be pushed about with a chilled knife blade to get them into position. All my work was done in a cold shed, which was kept open to the weather. It will be noticed that in these trials, both with prims and with snow, the temperatures were carefully noted, at frequent intervals, during the progress of the trial. These are the natural temperatures of the room where the work was done, and so of all the apparatus concerned in the experiments.

With these explanations I submit several illustrations of the behavior of ice prisms under a light pressure. These are in the form of abstracts made directly from my note-books, with only such corrections and explanations as seem necessary to a full understanding of each trial.

JANUARY 27th, 1869.—Temperature ranged from 12° F. to 22° F. during the following trials, which began on the 26th. Prisms of ice an inch thick by two inches were broken, and after matching them on the lines of fracture, were placed in clamps and subjected to a moderate pressure, the screws being tightened several times during the experiment. One prism was parted on the evening of the 26th and showed evident signs of reuniting.

The one that was permitted to remain in the clamps over night, therefore, some twenty-four hours, was so firmly reunited that in endeavoring to part it I thought the ice would break elsewhere. It finally yielded on the old joint to a force little less than sufficient to break the ice in any direction. There had evidently been a firm reunion, not a mere sticking together but a knitting of the joint.

FEBRUARY 3d, 1869.—Temperatures for Feb. 2d to Feb. 3d. Feb. 2d, 10 A. M. 7° F., 5 30 P. M. 13° F., 9 P. M. 11° F., 9 A. M. of Feb. 3d. 20° F. Highest temp., 20° F. The day of the 2d of February was bright but cold.

The prism of ice remained in the clamps with only moderate pressure for nearly twenty-four hours. The joint was firmly knit at the end of that time, separating with a snap under a strain, showing clear signs of actual welding. Proof that the union is not due to atmospheric pressure is furnished by the great ease with which the joint is separated when the pressure has been applied only a few minutes.

FEBRUARY 8th, 1869.—Temperatures, 9 A. M. 2° F.. 1 P. M. 19° F., 2.15 P. M. 20° F., 4 P. M. 22° F., 6.30 P. M. 20° F., 9.15 A. M., of Feb. 9th, 21° F., 10.30 A. M. 24° F. Highest temp., 24° F. A fine block of ice two inches square was secured in clamps at 9 A. M. of the 8th. Closed experiment at 10.30 A. M. of the 9th. The block separated on the joint with difficulty under a smart blow.

Feb. 21st, 1870.—Temperatures, 1.30 P. M. 21° F., 7.30 P. M. 12° F.. 7 A. M., of Feb. 22d, 6° F.. 2 P. M. 13 F., 3 P. M. 16° F. Highest temperature 21° F. Set three blocks in clamps and one without clamps.

No. 1 which had stood without clamps was parted with a light snap and readily.

No. 2, twenty-four hours in clamps, was crushed by the pincers in applying transverse strain, and yielded near to, but not on, the old line of fracture. It was shivered into fragments but the two faces were left firmly adhering.

Nos. 3 and 4 parted readily after lying in clamps twenty-four hours. This my notes conjecture to have been due to imperfect adjustment of their faces in placing them in the clamps.

JANUARY 4th, 1871.—Temperatures, 8.15 A. M. 2° F., 12 M. 9° F., 1 P. M. 9° F., 5 P. M. 11° F.. 10 P. M. 8° F., 6 A. M., Jan. 5th, 15° F.. 12 30 P. M. 26° F. Highest temp., 26° F. At 4 P. M. of the 4th placed in clamps a prism of ice near an inch and a half square and four inches long. Got a very perfect joint. Continued it under pressure till noon of the 5th. The union was quite perfect. Seized the ends of prism with cloth and could not break the joint over the edge of the bench by force. Then clamped it in two clamps and wrenched it apart. It parted only with violence, the separation taking place in a new line parallel to the old line of fracture.

The following trial is selected on account of the low range of temperatures.

JANUARY 7th, 1871.—Temperatures, 11 A. M. 12° F., 12 A. M. 12° F., 2 P. M. 12° F., 6 P. M. 9° F., 10 P. M. 3° F. Highest temp., 12° F. Three ice prisms were tested in the clamps from 11 A. M. and 12 noon until 10 P. M.

Two of them parted with moderate force. The third required much more force, about the same as would be required to break a prism of the same size. After separation, the surfaces of the old joint presented the torn, ragged appearance indicative of violent tearing apart.

The note here observes that the success of the experiment depends on getting the joint of the broken prism properly readjusted, so as to make the applied pressure bear evenly on all points of the joint. Failure to do this accounts for the imperfect adherence of some specimens.

JANUARY 18th, 1871.—Temperatures. This day before noon temperature ranged from 16° F. to 18° F.. 1 P. M. 16° F., 4 P. M. 15° F., 10 P. M. 6° F. Jan. 19th, 7.30 A. M. 0° F.. 12 noon 14° F.. 4 P. M. 22° F. Highest temp., 22° F. At about 11 A. M. of 18th put two prisms in clamps and continued one of them until 4 P. M. of the 19th. One of these much less than a square inch in cross section, was well united so as to lift sixteen pounds weight. The prism was somewhat crushed by pressure and gave way elsewhere than on the original line of fracture under a heavier weight. I finally wrenched the old joint apart, it giving way partly in a new direction.

JANUARY 10th, 1871.—Temperatures, Jan. 9th, 10.15 A. M. —4° F.. 12.15 P. M. —2° F., 1.15 P. M. —2° F., 2.15 P. M. 0° F., 4 P. M. 0° F., 10 P. M. —4° F. Jan. 10th, 6 A. M. —7° F., 12 noon 8° F.. 2.30 P. M. 9° F., 4.30 P. M. 8° F.. 9.30 P. M. 3° F. Highest temp., 9° F. On the 9th between 11 and 12 in the morning put a prism of ice in clamps and kept it there till 4.30 of the 10th. It was so firmly reunited that it did not part when subjected to a strain of thirty pounds. An addition of five lbs. more parted it. The test was made by securing one end of the prism and lifting a weight attached to the other end. The area of the cross section of the prism was less than a square inch by actual measurement.

A glance at this series of experiments with prisms shows that fragments of ice may be firmly re-united at all temperatures down to 9° F. which is the lowest maximum to which the ice was exposed in any trial. As to the main fact of the welding of ice at such temperatures, the evidence is conclusive. In order to avoid all suspicion that atmospheric pressure may have held nicely joined fragments in place, with sufficient force to account for the result, attention is called to the fact mentioned in the note of Feb. 3, "the great ease with which the joint is separated when the pressure has been applied only a few minutes." But, not content with this, the note of January 10, 1871, institutes a test by weight and measure. In this instance the highest range of temperature is 9° F. The prism is kept under the usual pressure during twenty-nine hours, and a firm union secured. The area of cross section measures less than a square inch, and the force necessary to pull the fragments apart exceeds thirty pounds. In my notebook comments on this trial, I find the conviction expressed that by long continued pressure the joint might be completely obliterated. And I remember that this remark was occasioned by the close knitting of the joint, and the growing indistinctness of the line of fracture in certain cases, under pressure.

I scarcely need call especial attention to the violence required in some cases to part the reunited fragments or to the fact that the second break sometimes occurs along a new line of fracture as in the note of January 4th. In regard to the influence of time as a factor in the reunion of the broken prisms, my impressions are strongly in favor of the value of time to the result. I have never known a prism which had only been exposed to pressure for a few minutes to show strong adherence. It is true that many prisms after being in the clamps a long while, fail to unite, owing to improper contact or uneven pressure, as is remarked in the above notes; but imperfect contact and uneven pressure could hardly be the cause of this so uniform parting of prisms which had been in contact only a short time —freshly joined faces come apart readily with a light snap. The trial recorded under date of January 27th, 1869, gives us a prism, subjected to pressure for a few hours, which shows "evident signs of reuniting," while one which has been kept in the clamps "some twenty-four hours was so firmly reunited that in endeavoring to part it I thought the ice would break elsewhere." So far as the evidence goes therefore, the element of time is an important one in the process; and this conviction has grown upon me during the years in which I have experimented upon both snow and ice.

As to the fourth point noted as being among the objects kept in view during these studies, it is difficult to conceive

how any moisture can intervene to assist in restoring the continuity of the faces of broken prisms. In discussing the effects of heavy pressure upon snow, this subject will come up again. But in the prisms, exposed to temperatures such as some of these were exposed to, and having all their sides free to the air, while pressure was applied at the opposite ends, it is difficult to conceive of any development of moisture to effect the result. It is very true that Mr. Tyndall, whose beautiful experiments upon ice have attracted the admiration of all readers, found lines of moisture developed transversely to the direction of pressure in masses of ice. But these observations were made upon ice at 32° or near that point. Here we have temperatures of all grades from 26° F. down to 9° F. The exhibitions of those inner lines or surfaces of moisture at a temperature close upon 32°, it is scarcely necessary to say, was due to the liquefaction of ice under pressure, according to the law given by the brothers Thomson. Inasmuch as water expands in freezing, it was observed that by preventing the expansion of water through pressure, that fluid could be reduced several degrees in temperature and still be kept in the fluid state. The brothers Thomson have given us the numerical expression of this fact in the rule evolved from experiment, that for every pressure of one atmosphere bearing on the fluid, its temperature may be reduced ·0075 of a degree of Centigrade without congelation. And conversely for every atmosphere of pressure brought to bear upon a mass of ice the temperature at which moisture can be developed in the ice will be lowered by ·0075 of a degree Centigrade. This is owing to the diminished volume of the ice under the pressure. But the application of this law to the case before us is out of the question. It would require by this rule a pressure of over 1950 pounds to the square inch to liquefy ice having a temperature of 30·2° F., and for the highest maximum temperature to which the prisms were exposed (26° F.) it would require a pressure of over 6456 pounds to the square inch. With the light clamps used no more than a few atmospheres of pressure were produced. I am thus explicit in the application of the principle brought out in the rule of the brothers Thomson, because the same considerations return in future experiments with snow under pressure.

The observations on the behavior of snow at comparatively low temperatures have been much more difficult than those upon ice prisms. Heavier pressures have come into play, and it is only by special contrivances that the conversion of snow into ice can be watched. My earlier trials, those to which allusion was made at Burlington and Chicago, were conducted with wooden moulds, into which the snow was packed, and the

pressure was brought to bear by means of a square wooden plunger, driven by an iron screw, which worked in a wooden frame. For these contrivances, which were, in many respects, very useful for earlier observations, I afterwards substituted a much more convenient iron press. The details of this press, it is hardly necessary to describe. The snow was packed in a cast iron cylindrical mould, having a smooth circular bore in the center one inch in diameter. The bore is three and one-half inches deep and of smooth finish, to lessen the friction of the snow. Into this bore works a plunger, also of iron, nicely fitted. The upper end of the plunger is attached to an iron head, grooved on its sides, so as to work along the vertical iron rods which are the uprights of the press. Into the upper side of this head the lower end of the iron screw projects and works in brass fittings—while the screw itself runs through an upper iron cross bar. By this means the plunger with its head can be carried down into the mould smoothly, by a slow motion of the screw. To the head of the screw a wheel was attached to which the power was applied by means of a cord passing over a pulley. To the cord weights were hung and their amounts noted. By this means a reasonably continuous and regulated pressure could be brought to bear upon the snow in the moulds. These moulds were split vertically through the middle, and were held together by a stout iron ring, which could be struck off with a blow of a hammer. When opened, the moulds exposed a vertical section of the little cylinder of ice resulting from the pressure. The slight differential motion of the pressed mass, on each side of the plane along which the mould was split, left a corresponding plane of easy cleavage in the resultant mass. Aside from the convenience of this whole arrangement, it gave me the advantage, that the conducting power of the iron, as exposed to low temperature, would help to prevent the accumulation of heat from the gradually increased pressure and slow downward motion of the plunger. The snow in the interior of the mould would thus be kept very close to the temperature of the external air.

I am under great obligations to my friend, Mr. Robert W. Willson, Assistant Astronomer in the Observatory in New Haven, who has very kindly assisted me to obtain the working power of this little snow press by actual trials. We have tested the force exerted at the lower face of the plunger for every five pounds of power up to fifty applied at the wheel. The observations, made and repeated by us interchangeably, to correct the personal error, have resulted in a very even rate, so that we have the pressure for every five pounds of power, and are enabled to extend the rate up to a power of sixty pounds at the wheel, which is the highest used. I can therefore insert in all

of the following trials with the iron press, excepting the first in which the screw was turned by hand, the actual pressure per square inch used. The natural temperatures of the room or shed in which the work was done are also carefully recorded, along with each trial, for every few hours of the day or days through which the trial lasted. With these explanations I give the following:

Experiments on Snow with the Iron Press.

DECEMBER 29th, 1870.—Temperatures. 9 A. M. 0° F., 1 P M. 3° F., 4 P. M. 3° F., 7 P. M. 2° F., highest temperature 3° F. At 9 o'clock A. M. packed the mould with snow and applied pressure very gradually until noon, making a quarter turn only of the screw at a time, so as to avoid evolving heat in the snow by sudden pressure. At noon the force necessary to turn the screw through the quarter had become considerable, though by no means violent. The screw was turned slowly through the quarter. Thus three hours were consumed in bringing the strong pressure to bear.

Discontinued the experiment at 7 P. M. The snow was converted throughout into perfect ice, white, clouded here with darker and there with lighter lines—translucent. This experiment is a perfect success. Everything has been manipulated with the utmost care.

JANUARY 4th, 1871.—Temperatures, 8.15 A. M. 2° F., 12 noon 9° F., 1 P. M. 9° F., 5 P. M. 11° F., 10 P. M. 8° F., 6 A. M., January 5th, 15° F., 12.30 P. M. 26° F.

Commenced experiment at 9 A. M. and discontinued at 6 A. M of January 5th. The highest temperature therefore to which the experiment was exposed would be 15° F. Result most perfect ice. At 9 A. M. subjected snow to pressure in new iron machine. Applied only very slight pressure gradually for some time by hand and then attached the wheel and weights, beginning with 16 lbs. (if we assume that I had brought the power up to 10 lbs. by hand this would be an additional power of 6 lbs.=346 lbs. additional pressure) and increasing the weight gradually to power 60 lbs.=4122 lbs. pressure per square inch. The pressure was thus kept nearly continuous, the snow yielding very slowly to each addition of weight. On adding the last 15 lbs.=1054 lbs. additional pressure*—the machine was left standing through the night, but the wheel was turned through only about a quarter circle during the whole night This I think is the most perfect ice I have formed as yet, at low temperatures and under slowly applied pressure. It was perfect gray ice uniform throughout, not clouded.

JANUARY 9th, 1871.—Temperatures, 10.15 A. M. −4° F., 12.15 −2° F., 1.15 P. M. −2° F., 2.15 P. M. 0° F., 4 P. M. 0° F., 10 P. M. −4° F. January 10th, 6 A. M. −7° F., 9.30 A. M. 0° F., highest temperature 0° F. Commenced pressure at 10.15 A. M., after having allowed the mould packed with snow to stand for some time. No pressure applied after packing, except by means of wheel and weights over pulley. Commenced with weight of three pounds = about 375 lbs. pressure, and then added two pounds, etc. Discontinued at 9.30 A. M. of the 10th, the thermometer marking 0°. Highest weight used 60 lbs.=4122 lbs. pressure per square inch. Result perfect, mass changed to ice throughout of remarkably clear and every way fine quality. The weight was increased very gradually, only a few last additions being made in quantities of 6 or 8 lbs.=400 to 550 lbs. pressure. At this point the motion became very slow. The press was left over night with a weight of 60 lbs.=4122 lbs. pressure per square inch, and the screw did not probably make more than a quarter turn during the night and up to the time of closing the trial. The snow used was slightly granular.

JANUARY 18th, 1871.—Themometer up to 12 noon has ranged from 16 to 18 F., at 1 P. M. 16° F., 4 P. M. 15° F., 10 P. M. 6° F. January 19th, 7.30 A. M. 0° F., 12 noon 14° F., 4 P. M. 22° F. Highest temperature to which snow was exposed while under pressure was 18° F. The mould was packed with snow last night (the

*The resulting pressure for each additional pound of power diminishes as we go into the higher numbers, owing to increased friction.

17th) the thermometer standing at 16° F.* This morning began with 1 lb. and continued to increase the weight up to 25 lbs. total=1693 lbs. pressure. Discontinued at 11·30 o'clock the 19th. Transformation into ice incomplete. The mass melted partly as ice but the lower portion of the cast from the mould melted more like snow. Notice that less than half the previous weight had been used.

Here are four trials with the iron press, all purposely varied, and all but the last resulting in perfectly formed ice – the ice character in the last instance being developed in the upper portion of the mass, while the lower portion melted more like snow. This test of perfect and imperfect glaciation is worthy of notice. In no way is the true ice character better exhibited than by exposing the mass to a slow melting temperature. If the union of the snow crystals is complete, the mass melts only at the surface, like lake ice, whereas if the conversion into ice is imperfect the mass, as the melting goes on, begins, after a time, to disintegrate and betray a granular structure. Other tests such as whiteness and opacity or their opposites are less reliable. For, though the mass usually clears up under prolonged pressure, the glaciation may be far advanced in a mass which retains much of the whiteness of snow. Nevertheless the usual result is a tolerably clear ice of a grayish appearance owing to the retention of air bubbles. It so happens that the maximum temperature, to which the snow under pressure was exposed, is lowest in the three cases where the resultant ice was most perfect. For these three the highest temperatures are severally 3° F., 15° F., 0° F., and for the last trial 18° F. On the other hand in the second and third of the series, the highest pressure exerted is equal to 4122 lbs. to the square inch as against 1693 lbs. to the square inch in the fourth trial. In the first of the series the power was applied by hand and can not be certainly given, though, as the final power applied is described as "considerable, though by no means violent," it was doubtless much less than 60 lbs. power. It would probably be safe to take it as equal to 45 lbs. which would give an effective pressure of 3068 lbs. to the square inch.

In the first trial I ask the reader further to notice the manner in which the pressure was brought to bear. The screw, which had six threads to the inch, was turned only through a quarter circle at a time, and each quarter was made slowly, so that three hours were consumed before the full pressure of 3068 lbs. to the square inch was brought to bear. As the mould was always packed full of snow, and as the resultant ice usually occupied one-half the depth of a bore $3\frac{1}{2}$ inches deep, this would give a descent of the screw through $1\frac{3}{4}$ inches in three hours, making $10\frac{1}{2}$ revolutions of the screw in 180 min-

* This was done in order to let the whole stand over night without pressure and allow the temperature of the snow and press to become equalized.

utes, or, on an average, a revolution in 18 minutes. But as there was, doubtless, a pause of several minutes between each quarter turn, and perhaps occasional long pauses, the motion of the screw would, while in motion at all, be faster than this, though in any case very slow. It is well to note these features of the trial and to remember that the trial was made in a cast iron mould surrounded by an atmospheric temperature as low as 3° F. Such facts have an important bearing on the possibility of the development of heat under pressure and consequent liquefaction of the snow. In this respect the trial under date, Jan. 9th, 1871, is also instructive. Here a like process of gradual increments was gone through, and here we have additions of power numerically expressed. The weight was increased very gradually (no hand power being used) three pounds to start with equals about 400 lbs. pressure, under which of course the lightly packed snow was yielding; then two pounds, etc., until, only at the last, increments equal to from 400 to 550 lbs. effective pressure were used.

In the fourth trial, beginning was made with only one lb. power, and increase made up to 25 lbs. power.

The times also vary in the four trials, and this fact has its value, though upon that point other and earlier experiments made with wooden moulds are more valuable. For convenience the conditions and results of these four trials may be grouped together as follows:

No	Date.	High't Temp.	Duration of Exp.	Increments of Effective Pressure.	Resulting Condition.
1	Dec. 29, '70	3° F.	10 hours	Very small by hand, total 3,068 to squ. inch.	Perfect ice.
2	Jan. 4, '71	15° F.	21 hours	Small by hand at first, then 346 lbs. and gradually to total 4,122 lbs. to squ. in.	Most perfect ice.
3	Jan. 9, '71	0° F.	23 hours	375 lbs., 250 lbs., 400 to 550 lbs., total to square inch, 4,122 lbs.	Remarkably clear ice.
4	Jan. 18, '71	18° F.	24 h's +	150 lbs. with additions, to total of 1,693 lbs. to square inch.	Upper part of mass true ice.

From this table and the preceding explanations, the following conclusions are reached:

(1.) Snow may be converted into ice under pressure at a temperature as low as 0° F.

(2.) At a temperature of 3° F. no more than 10 hours are required to complete the process, under a very slowly applied pressure and with gradual increments, until the total reaches probably not more than 3,068 lbs. to the square inch.

It is as well here, as anywhere perhaps, to notice a marked peculiarity of ice and snow under pressure. When a prism of cold ice is placed in the clamps and any given amount of pres-

sure brought to bear upon it by screws, the pressure will not remain constant. The prism will very slowly yield to the pressure, by what seems to be a molecular movement; and if the pressure is to be kept up, it becomes necessary to tighten the screws after a comparatively short time. I regret that the lateral expansion, which may be supposed to attend this longitudinal yielding, was not measured. That such a longitudinal yielding takes place is impressed upon my mind, as a constant experience, and I think there can be no mistake about it. Indeed I find attention called to it in my notes made on the spot, and it will be remarked, that occasional tightening of the screws is mentioned in the prism experiment of Jan. 27, 1869. It is my belief that this molecular yielding of the ice takes place at all temperatures. A parallel fact has certainly been observed, at all temperatures, when snow was being converted into ice. Even with the heaviest pressures used and after the glaciation has been completed, the mass still continues to yield under the pressure. Here in a firmly bound iron mould, there can be no lateral expansion, but the ice particles seem to approach each other and compact themselves, not to expand again when the pressure is removed. It is impossible to keep the screw tight without a weight movable over a pulley. If the screw be tightened by hand and left for an hour or two, the ice contracts under it and leaves room so that the next slight turn of the screw is comparatively easy.

Having thus established the main fact of the glaciation of snow of low temperature under pressure, we come to the discussion of the question whether, under the circumstances of these experiments, we are to suppose that glaciation is due to the production of water, or at least of moisture, under the pressure applied.

For this purpose it will be necessary to combine with the observations above given, some earlier ones, made with wooden moulds, fitted with wooden plungers. It will be understood that trials next to be mentioned were of that kind. It is not necessary to discuss in this connection the rule of the brothers Thomson, mentioned above. The considerations advanced in regard to the prisms apply equally to the glaciation of snow. The temperatures involved are far out of the way of that law of liquefaction. I purpose, rather, to lay before the reader the actual facts of observation, gathered from numerous efforts to determine the question.

The question of liquefaction at low temperature, according to the law of the brothers Thompson, being disposed of, another question arises: whether in the mass of snow under these larger pressures sensible heat can by any possibility be developed sufficient to account for liquefaction. In the outset such a

supposition seems wholly unwarranted. I have only to refer to the production of ice in the iron press, with its slow and intermitted motion, in order to call to mind the extreme improbability of a rise of temperature from near the zero point to the point necessary for liquefaction under the pressures used. Moreover, I have endeavored by actual trials to obtain the extreme effect of such pressures as have been used—pressures not so great indeed as the highest of those used with the iron press—but great enough to convert snow into ice at very low temperatures.

The most reliable of these observations have been made upon not very cold snow with pressures rising from 580 lbs. to the square inch, to a possible maximum of 2,000 lbs. to the square inch. I shall hereafter give cases of the glaciation of snow of low temperature under the latter pressure. The method of testing has been as follows: The temperature of the air, and the snow before pressure is noted, and in some cases, also, the temperature of the moulds. Then pressure is rapidly applied to the snow in the moulds by sudden impact of the screw. A wire in the bottom of the plunger leaves a fine bore in the pressed snow for the insertion of a thermometer, and the temperature of the snow is noted immediately on withdrawal of the plunger. In some instances pains have been taken to aggravate the rise of temperature by sudden and violent impact; throwing myself on to the handles of the screw with all my might. Now the highest elevation I have been able to obtain by this violent method of applying a pressure of 1,500 to 2,000 lbs. to the square inch, during only one minute, was $3\frac{3}{4}°$ F. The pressure exerted was my whole strength applied to the handles of the screw by sudden and violent efforts. Unfortunately the temperature of the moulds before pressure was not observed.

In the very next observation recorded, I find the same operation gone through with, except that the violent impulses were repeated, at intervals, during twenty minutes. The pressure was the same as before, but the elevation effected was only $1\frac{1}{4}°$ F. Here also the temperature of the moulds was not observed. I have before me another instance where the same pressure was applied, only during two minutes, to a mould filled with bits of ice. The temperature of the air and of the moulds before pressure are noted at 27° F. The ice before pressure measures 25° F., and after pressure 27° F. The elevation in this case was doubtless aided by that of the moulds. and in the case before given, when the temperature after pressure rose to $3\frac{3}{4}°$ F., it is very probable that the temperature of the moulds was higher than that of the snow; while in the second case, there is reason to think it was lower than that of

the snow before pressure. In this way the $3\frac{3}{4}°$ F. would be too much and the $1\frac{1}{2}°$ F. would be too little. From numerous observations, I am well satisfied that the effect of pressure *quietly applied*, would not exceed a degree, or a degree and one-half of Fahrenheit; and where *special pains are taken to avoid elevation of temperature*, its effect will be so diminished that they may be left out of the account, in experiments conducted a number of degrees below freezing. If it is said that the method of taking the temperatures is crude, this must certainly be admitted. But it is the best that could be devised. I have indeed attached a thin, hollow pointer of iron to the plunger, in the center of which I carried a thermometer down into the snow and strove by this means, to get at the temperature during pressure. But after numerous trials, the indications proved to be so unreliable that I have discarded the results. It may be said, however, in favor of the proximate accuracy of the temperatures quickly taken after the pressure is removed, that. as the snow is not elastic, the heat evolved by pressure will not be absorbed again on its withdrawal.

So far as the observations went they were entirely confirmatory of the above conclusion. The thermometric evidence being against the supposition of any development of moisture by heat, I so arranged matters that I could actually watch the the progress of glaciation, while pressure was being applied. Wooden moulds were prepared with glass windows of about an inch in diameter in the opposite sides. These moulds were as usual in halves, bolted, so that the resulting ice could be exposed. Through the windows, which were of very heavy plate glass, I watched the progress of glaciation from beginning to end. But the closest scrutiny failed to disclose any signs of moisture. Of any free and abundant flow of water through the snow such as is seen at a temperature of 32° F., it will be understood we are not here discoursing at all. Any such thing would have been readily detected without nice contrivances. We are considering only the production of a proper moisture, which might be forced through the mass so as to wholly permeate it. Of such moisture I found no trace in the lower temperature experiments. When the pressure had been well brought to bear, a change could be seen coming over the mass, as will be detailed in a trial given below. The snow in the mould, as seen through the glass, began to have a glazed appearance, and soon seemed to be losing its whiteness and opacity. This change went on gradually until the whiteness of the snow was nearly gone. I could discern upon the glass no trace of condensation of moisture, no clouding as if by a breath, though the temperature of the room was only a few degrees above zero of Fahrenheit.

Another attempt was made to detect the presence of moisture. I sprinkled into the snow little particles of water-paint. These paints are quite sensitive to moisture; so much so that, if buried in lightly packed snow without pressure, at a temperature as low as 12° F., they attract moisture and soften by an action similar to that of common salt. And when barely touched to really moist snow of 32° F., the snow is promptly discolored with a blotch which spreads around the point of contact.

Now it is manifest that this paint furnishes a delicate test of the presence of moisture. If at temperatures lying in the region of zero Fahrenheit moisture were being forced through the interstices of the snow, even in minute quantity, it would necessarily carry with it some traces of color from the paint sprinkled in the mass; and this is observed to be the case with snow under pressure near to 32°, the paint spreading in large blotches. At a temperature as low as 20°, the paint seems to liquefy the snow to such an extent, that if it be introduced with the snow into the moulds, it will become quite moist and will perhaps form a blotch. I infer that the blotching at this temperature is due to the liquefying action of the snow, because as will be seen in the trials detailed below, no sign of such spreading could be detected at the temperature under which glaciation was there effected. It must be regarded as certain therefore, that if moisture is developed at any time during the process, it is not developed until the snow has been so completely consolidated as to prevent the passage among its particles of even so minute a quantity of moisture as would be necessary to carry color along with it. But snow so consolidated would be little if any short of ice. I have thought it better to state the points involved in the following observations before giving their details.

Observations with wooden moulds.

Experiment No. 1, February 7th.—Temperatures. 12 noon 9° F., 4.20 P. M. 3° F., 9.50 P. M. —7° F., 7.30 A. M. February 8th. —21° F., highest temperature 9° F.

The screw was gradually brought to bear with considerable power, no pains being taken to avoid accumulating heat. In about two hours a change was manifest in the snow. It began to have a glazed appearance and soon seemed to be losing its whiteness and opacity. This change went on gradually, until, at about 10 P. M., the whiteness of the snow, as seen through the glass, was nearly gone. It was allowed thus to stand over night. At 9.30 A. M. the pressure was taken off. The ice was perfect. The whole prism had lost its opacity so far as to transmit the light, the snowy whiteness was gone and the whiteness of ice—a gray ice had taken its place. A layer of particles of water paint was in full view, on the top of the resulting prism (the bore of the wooden moulds was square), just under the surface. There was not a sign of the color having spread. Their angles were perfectly sharp and their lines perfectly well defined. The same was true when the prism was opened. The particles scattered through the mass exhibited no sign of spreading.

Experiment No. 2.—Snow used marked on the ground 5° F. Temperatures, 9.45 A. M. of February 10th 3° F.—during the day near 0° F. 10 P. M. —6° F., 9 A. M. of February 11th —5° F., 10 P. M. 4° F., 7.30 A. M. of February 12th 6° F., 8.30 A. M. 7° F. Duration of trial from February 10th 9·45 A. M. to February 12th 8.30 A. M., making 47 hours nearly.

Used here a pair of deep moulds, packed full of snow, which accounts for the imperfect glaciation of the lower portion. The bottom was granular snow. Then came vitreous snow. These two occupied one-third the length of the prism. Then came ice of a grayish appearance, increasing in perfection to the well defined ice of the upper portion. The ice is whitish or turbid but well characterized. The water paint in the prism shows not a trace of running. The angles are sharp and the lines sharply defined. On the line between the snow and ice two particles of paint were lodged, but here there had been no change in their appearance.

Experiment No. 3.—Temperature of air February 22d, 1868, at 9 A. M. —4° F. Temperature of moulds —4°. Temperature of snow in moulds before pressure —4°. Snow used was granular.

Temperatures. 9 A. M. —4° F., 12.15 P. M 0° F., 2 P. M. 0° F., 4 P. M. 1° F., 7 P. M. —2° F., 9.40 P. M. —7° F., 8 A. M. of February 23 —5° F., 1 P. M. 0° F., 9.30 P. M. —5° F. February 24th, 7.30 A. M. —10° F., 9 A. M. —7° F. Duration 48 hours. Opened and found a gradual transition from granular snow at the bottom of the prism to perfect ice at the top. The ice was clear and fine. The paint used in this experiment was very finely divided, so that the particles might be affected by the least moisture, and yet in the best of the ice there was no trace of a spreading of the color. Each particle was a distinct speck in the ice.

In looking over the various observations upon snow, in connection with those made upon prisms of ice held in clamps, everything seems to negative the supposition that, at the low temperatures used, moisture intervenes to prepare the way for regelation. In the case of prisms fully exposed to view, there is no sign of such a process. Also in the case of prisms, and snow as well, it has been shown that the rule for the depression of the point of liquefaction cannot apply under such pressures as have here been used. Neither is there good reason to suppose that the development of sensible heat is sufficient to have an important bearing on the results. Moreover, inasmuch as regelation is of necessity an instantaneous process, the evidence that time plays a not unimportant part in the process by which continuity is established between fragments of ice as weli as snow particles, though that evidence hereafter to be reviewed is not as definite or complete as could be wished, bears, so far as it is allowed weight, against the application of that theory to the facts here insisted on.

I would not however be supposed to overlook possibilities which must be contemplated in this connection, though they seem remote. It may be conceived, that, in the case of prisms and of snow packed in moulds, inasmuch as it is not possible to bring the pressure to bear evenly, either upon all points of fractured faces of prisms, or upon all points of the mass of snow, there might be now here and next there a concentration of pressure locally upon molecules, in consequence of which, now at this point and next at another, slight moisture might be developed, in which case true regelation would take place. In

this form my friend Mr. Willson has suggested to me a possibility, akin to one which I myself had considered, namely that of local leverage among the particles, by which large local pressures might be concentrated here and there in the mass. But it must be remembered that the paint test demonstrates that there can be no speading of moisture from such centers; and as a further counter-suggestion, Mr. Willson points me to the fact that we should, in this way, secure only partial re-union, at single points along the faces of fracture in prisms, and only local glaciation of the snow at scattered centers, instead of the uniform glaciation of the whole mass, which results when the pressure is prolonged.

It remains only to lay before the reader such evidence as the facts give us of the influence of time upon the processes we are discussing.

I think it will serve our purpose best, at this point, to introduce a brief tabular exhibit of quite a number of trials, arranged in the order of temperatures; premising that an unavoidable indefiniteness attaches to the contained results. Those pressures which had to be estimated are given within maximum range only. I think I am perfectly safe however, in saying that I have given an exaggerated extreme upper limit. Besides this it is to be noted that pressures exerted in this way, upon a yielding mass of snow in a mould, do not tell upon the lower portion of the mould, until the snow has had time to settle away and the pressure is followed up. So that full effect is at first experienced only near the face of the plunger, and then only for a short time: after which, the yielding of the mass relieves the pressure. This introduces an element of uncertainty—by bringing the amount of pressure for a great deal of the time, and for a large portion of the mass, below the figures taken to express it. It is evident, too, from a glance at the table, that we can not state the minimum of time and pressure required at any given temperature for glaciation. All we can do is to say, that, at particular temperatures, and with certain pressures, no more than a certain length of time is required. We have only some evidence regarding minimums. It will be noticed also that here ice is not considered perfect, unless the snowy whiteness has been in a good degree replaced by a darker shade, more approaching that of lake ice, and unless there has been an elimination of the granular structure.

Tabular Exhibit of Observations on Snow.

No.	Temp. F.	Time.	Pressure to square inch.	Result.
1	32°	1 m.	242	Gray ice, imperfect.
2	32	2·5 m.	950–1275	Sub-vitreous, sub-granular, gray ice.
3	32	3 m.	532	Gray ice, imperfect.
4	29	3 m.	950–1275	Snow and coarse granular, very good ice.
5	27·5	1 m.	580	Hard but quite granular.
6	26	1 m.	1475–1975	Sub-vitreous, sub-granular.
7	26	24 h.	950–1275	Very perfect, pretty clear ice.
8	25	1½ h.	1475–1975	Very perfect ice.
9	24·5	10 m.	580	Sub-vitreous, granular.
10	23·25	20 m.	1475–1975	Sub-vitreous, grayish, sub-granular.
11	23	20 m.	1100–1465	In five minutes snow-darkened, glaciation surely complete.
12	22	3 h.	950–1275	Vitreous, dark, translucent ice character well advanced.
13	21	45 m.	950–1275	Good ice, rather white.
14	20	2 m.	950–1275	Sub-vitreous, opaque, granular, pure white.
15	20	10 m.	575– 775	Sub-vitreous, granular.
16	20	3 h.	1200–1600	Good ice.
17	18	24 h.	1693	True ice but not as perfect as some.
18	15	21 h.	4122	Perfect gray ice uniform throughout.
19	9	22 h.	1475–1975	Change manifest in two hours and in ten hours change was far advanced, perfect gray ice.
20	7	47 h.	1475–1975	Perfect ice.
21	4	5 h.	1475–1975	Highly vitreous, dark, melts with only slightly granular structure.
22	3	10 h.	3068	Perfect ice.
23	1	48 h.	1475–1975	Perfect ice.
24	0	23 h.	4122	Remarkably clear fine ice.
25	−2	2 h.	1475–1975	Highly vitreous, further advanced than No. 21.

If, with the above explanations in view, we direct our attention to special portions of the table, we find, in the first place, that at 32° F., with a very moderate pressure, a gray ice may be obtained in from one to three minutes; and no marked difference is observed between ice produced under an extreme pressure of 250 pounds to the square inch, and that produced under higher pressures.

No. 6, with temperature of 26°, subjects snow to a pressure of from 1475 pounds to 1975 pounds to the square inch for one minute. This high pressure, favored by a not very low temperature, fails in so short a time to produce perfect ice, while in No. 7, at the same temperature, under a lower pressure, we get in 24 hours "very perfect, pretty clear ice."

At 25° F. No. 8 gives us very perfect ice in an hour and a half under a pressure of from 1475 pounds to 1975 pounds per square inch; and still better is No. 11 in which, at a temperature of 23°, and under a pressure ranging from 1100 pounds to 1465 pounds to the square inch, we get a nearly complete gla-

ciation in twenty minutes, with some darkening of snow in five minutes.

In the next five trials, from No. 12 to No. 16 inclusive, we have a range of only two degrees of temperature, and such a relation of times and pressures as will throw, perhaps, some light on the point under discussion. We will arrange these five trials in order, according to the perfection of the ice:

No. 15	20° F.	10 m.	575 to 775 lbs.	Sub-vitreous, granular.
No. 14	20° F.	2 m.	950 to 1275 lbs.	Sub-vitreous, opaque. Granular, pure white.
No. 13	21° F.	45 m.	950 to 1275 lbs.	Good ice: rather white.
No. 12	22° F.	3 hours	950 to 1275 lbs.	Vitreous, dark, translucent. Ice-character well advanced.
No. 16	20° F.	3 hours	1200 to 1600 lbs.	Good ice.

The pressures in Nos. 14, 13, and 12 are the same, and the temperatures so near together as to point pretty distinctly to the influence of time.

Passing over the higher pressures and long times in the lower part of the table, I call attention to Nos. 21 and 25. There is an apparent discrepancy between these two, which is probably due to a heavier pressure, within the range set down, being brought to bear upon No. 25. These two trials show, however, that even in a couple of hours at a temperature as low as −2° F., under a pressure certainly less than 2,000 pounds to the square inch, glaciation may be very far advanced; but it is still to be noticed that the terms expressing the result are much more positive in No. 23, for instance, where, with only three degrees difference in temperature, the long continued pressure of like range gives perfect ice; and it will be noticed that when we come among the lower temperatures such strong expressions are only used where the pressure has been long continued. These facts taken with those of like nature observed when experimenting upon prisms; taken also with a general experience running in that direction, incline me to the conclusion that time is a very important factor in the process of glaciation. Impressions early made by observations have grown into a strong conviction that glaciation would take place in a few days under the moderate pressure of say 1,000 pounds to the square inch, allowed to bear quietly and continuously on snow the temperature of which did not exceed that of zero, Fahrenheit.

The results of these observations may now be briefly summed up. We may regard as established—

(1.) That broken prisms of ice, at temperatures far below 32° F., will firmly reunite if the faces of fracture are brought together and a very moderate but long continued pressure is applied.

(2.) That snow is converted into ice under a long continued pressure, not exceeding 2,000 pounds per square inch, and probably much less than that, and at temperatures near to zero Fahrenheit.

(3.) That while great pains have been taken to detect the presence of moisture in the snow while under pressure at these temperatures, no satisfactory evidence of its presence has been obtained, the various tests failing to give it; while, on the other hand, the possibility must be entertained of the local development of moisture in centers of concentrated pressure; though the paint trials demonstrate that, if produced, it does not flow from the centers, and so a serious difficulty arises as we contemplate this possibility as influencing the result.

(4.) That the evidence is not inconsiderable in favor of the influence of time as a factor in the establishment of continuity between fragments of ice and between snow crystals and, insofar as this consideration is admitted, it militates against the supposition of liquefaction and regelation at these temperatures.

ART. LII.—*Communications from the U. S. Geological Survey, Rocky Mountain Division. I. On the minerals, mainly Zeolites, occurring in the basalt of Table Mountain, near Golden, Colorado;* by WHITMAN CROSS and W. F. HILLEBRAND.

[THE communications, of which the following is the first, are intended as preliminary notices of interesting facts, in cases where the publication of the report which would embrace them is necessarily delayed for a considerable length of time.

In the course of an investigation, now being carried on in this division, into the geology of a portion of the eastern flanks of the Colorado Range near the town of Golden, the opportunity presented itself of making a study of the interesting basaltic flows at that point, and the minerals contained therein. The present contribution by Messrs. Cross and Hillebrand gives a brief description of the species thus far fully determined, viz: chabazite, thomsonite and analcite. The latter mineral has hitherto been supposed by many persons who have collected it at this point, basing their assumption on statements made in the Hayden Reports,* to be leucite, which is believed to be unknown elsewhere in this country, except as a microscopical constituent of certain rocks, collected by me in Wyoming, when on the Fortieth Parallel Survey. Since the Colorado leucite proves to be analcite, the Leucite Hills of Wyoming seem to be still the only known locality of leucite in the United States.

S. F. EMMONS, *Geologist in charge.*]

* Annual Report of the U. S. Geol. and Geog. Survey of the Territories for 1873—pp. 130 and 359.

Table Mountain is situated upon the plain, twelve miles west of Denver, although it approaches so near to the abruptly rising foot-hills, composed of Archaean schists, that the intervening space is scarcely more than a mile in width. Within this space, however, are exposed the upturned edges of strata of the Trias, Jura, and Cretaceous, including the coal-bearing horizon of the Laramie formation; dipping very steeply east.

Table Mountain owes its existence to a sheet, or rather in most parts, to two sheets of basalt, which have in a measure protected the underlying strata from erosion. Through that agency the upturned strata adjacent have been denuded until a valley several hundred feet deep has resulted, separating Table Mountain from the foot-hills.

The horizontal strata of Table Mountain seem at first sight markedly unconformable with those so near by, but this appearance is due to the location of this valley of erosion directly in the sharp fold. In other places the conformability is distinctly shown.

Opposite the mountain, Clear Creek issues from the foot-hills and has cut a gorge directly through it, forming what are known as North and South Table Mountains. On the banks of the creek, behind the mountain, is situated the town of Golden.

The mountain is a plateau or *mesa* of not more than four to five square miles in area, with an average elevation above the bed of Clear Creek of about 700 feet.

The source of the basalt is in certain dykes situated to the north and northwest, whence the lava spread out in a sheet and flowed to the south-southeast. The lower sheet averages one hundred to one hundred and fifteen feet in thickness, and possesses the structure of a stream which has flowed upon the surface. Adjacent to the underlying strata, is a layer of a very porous structure, about one foot in thickness; then follows massive compact rock for seventy feet, while the upper forty to fifty feet show many cavities, large and small, more or less flattened and drawn out, and the surface is rough and jagged. The first sheet was covered by a second, of identical composition, before erosion or decomposition had produced noticeable effects. Of the second sheet, only the massive lower part remains, and its thickness, as well as the lateral extension of both sheets, can only be a matter of conjecture. The rock is a feldspar basalt of very simple composition; rather coarsely crystalline in its massive parts, and in the porous with a groundmass which becomes finer-grained as it approaches the contact or the surface. A glassy base, now much devitrified was formerly present in the porous parts.

In the cavities of the upper portion of the lower sheet are

many beautifully crystallized zeolites, associated with calcite and aragonite. The mode of occurrence varies somewhat in different parts of the mountain, and a few species seem to be locally restricted, but most of those to be described can be found in abundance and well developed.

At a point on the southern face of North Table Mountain, where the greatest number of species occur together, the students in the school of mines at Golden began blasting for specimens several years ago. During the present investigations the locality was still further opened, and absolutely fresh and clear material obtained. Up to the present time, the following species have been definitely determined, viz: analcite, apophyllite, aragonite, calcite, chabazite, mesolite, natrolite, stilbite and thomsonite. Several others are in process of investigation, some of which will doubtless prove to be modifications of some of the species mentioned. In the further description, the order to be followed is primarily that of deposition at the above locality, where frequently as many as six or seven species occur together.

The only previous notice of this mountain is embodied in the report of Arch. R. Marvine, in Annual Report of the U. S. Geological and Geographical Survey of the Territories for the year 1873, pp. 129–131, but the information given is exceedingly meager, and in part entirely incorrect.

The Survey is indebted to Professor A. Lakes, of the School of Mines, for calling special attention to Table Mountain.

1. *Chabazite.*

This mineral seems to be the oldest of the zeolites, with the exception of certain peculiar stratified deposits in some of the cavities, the character of which has not been fully determined. It was however preceded in some places by yellow calcite, as will be described later.

In most cases where several zeolites occur together, chabazite forms a coating to the cavity, and upon it the others are deposited. It frequently occurs alone however and excellent specimens are abundant. The glassy, white, or rarely pinkish crystals have the usual rhombohedral form, and the faces are occasionally as much as 1 cm. in diameter. The crystals are usually twins of interpenetration.

In some of the smaller cavities are sub-dividing walls of chabazite, or miniature columns composed of many small crystals.

A second generation of chabazite came after thomsonite and analcite, but the crystals are few and very minute. No optical or chemical examination has as yet been made.

2. *Thomsonite.*

This zeolite followed closely upon the chabazite, indeed its earliest aggregates are so intimately associated with that mineral, as to make it evident that the deposition of the one had begun before that of the other had ended. The mineral occurs in very minute rectangular blades, which are placed upon each other like the leaves of a closed fan, and the very compact combinations of such aggregates are usually arranged in a more or less distinctly radiate manner. Sometimes spherical forms result; in other cases, columns, by radiation from an axis; or less frequently, walls, the blades standing at right angles to the central plane. Where crystals of yellow calcite were not covered by chabazite, the thomsonite has never failed to coat them, the blades being approximately perpendicular to the crystal faces. When a large surface of chabazite has been completely coated by the more or less radiate aggregates of thomsonite, forming an undulating surface, the whole has a most delicate silken lustre, while that on a fractured surface of a spherical mass is more satin-like. The aggregates are white when pure; single blades are transparent.

It is difficult to obtain isolated leaves, and they are then so thin as to affect polarized light but slightly; still, it was definitely determined that the direction of total extinction between crossed Nicols is parallel to the longitudinal axis. By examination of the ends of the blades, under the microscope, with a power of ninety diameters, it could be seen that the vertical edges were formed in many cases by a plane at right angles to the dominant surface; occasionally a prism with angle very near 90°, and in a few cases both forms together were seen. These planes correspond to the macropinacoid (dominant), prism and brachypinacoid of thomsonite as given by all authorities. The termination seems to be the basal plane. The average thickness of these blades is about $0{\cdot}01^{mm}$. Toward the close of the zeolitic formation, a second generation of thomsonite was deposited. The blades are in this case longer than those of the first, while the other dimensions remain about the same.

In combination with the basis upon the crystals of this latter growth are apparent brachydomes, whose angles with the basis were most frequently measured at about 145° or 135°.

The blades of the second generation, when deposited upon those of the first, have the same crystallographic orientation, and serve simply as prolongations of the latter. Through the usual slight yellowish tinge of the recent growth, the line between the two is clear.

The long blades of the second growth of thomsonite often form bundles resembling rough prismatic crystals, and these

bundles arranged in a loosely and irregularly radiate manner form bunches an inch or more in diameter, upon which the delicate needles of mesolite have a special tendency to deposit themselves. Reference will be made to this again later.

Of the following chemical analyses, that under I is of the older, and that under II of the more recent growth. In each case the percentages under *b* denote repeated determinations. The material for I was carefully selected with a view to purity. The imperfectly spherical aggregates were broken up quite fine, and each particle appropriated for analysis was first closely examined with the loupe, in order to detect any trace of chabazite. Analysis II was made of material taken from one of the bunches above described. The microscope showed that minute hairs of mesolite were so intimately associated with the thomsonite as to render their *complete* removal impossible. The specimen chosen had comparatively few of them, and the increased percentage of SiO_2 probably indicates the amount of the impurity present.

	I.		II.		III.	IV.
	a.	*b.*	*a.*	*b.*		
SiO_2	40·681	40·703	42·662		41·6	40·877
Al_2O_3	30·117	29·749	29·252	29·286		
CaO	11·921	11·895	10·900	10·900		
Na_2O	4·444		4·920			
H_2O	12·857		12·275	12,337		
	100·020		100·009			

From the above figures, the following oxygen ratios are obtained:

	RO	:	Al_2O_3	:	SiO_2	:	H_2O
I.	1	:	3·09	:	4·76	:	2·51
II.	1	:	3·10	:	5·17	:	2·48

These ratios agree quite well with those in the variety formerly called mesole or faröelite. But that thomsonite which seems to be considered by Dana, Rammelsberg, Naumann-Zirkel and others, has a ratio of about $1 : 3 : 4 : 2\frac{1}{2}$, and Dana* directly intimates that the high percentage of silica in mesole, is due to an admixture of quartz, mesolite, etc. Thinking it barely possible that some chabazite had escaped notice in obtaining material for I, thus increasing the percentage of silica, a second portion of thomsonite from the same specimen was procured, by simply breaking off the *ends* of the blades, and this was found to contain 41·6 per cent. SiO_2 (III). A microscopic examination of this material showed that these blades

* A System of Mineralogy, ed. of 1874. p. 424.

of thomsonite contained very small, irregularly rounded particles, imbedded in the outer surfaces. These particles which are clear, or slightly yellowish, do not affect polarized light perceptibly, and are not crystalline in form. They are present in varying quantity toward the termination of nearly all blades, but are usually entirely wanting in the lower portions of all aggregates.

Analysis IV was made from material taken from the purest and finest specimen of thomsonite as yet obtained. Here the deposit of thomsonite was unusually thick, and the separation from the underlying thin layer of chabazite was complete. The particles above referred to were present in very small quantity in the upper part of the blades, and even if they consisted of pure silica could have affected the result but slightly.

While believing that the results obtained indicate a greater variation in the composition of thomsonite, than is allowable under the generally accepted formula of Rammelsberg,*

$$\left\{ \begin{matrix} m\,(2CaAlSi_2O_8 + 5aq.) \\ n\,(2Na_2AlSi_2O_8 + 5aq.) \end{matrix} \right\},$$

the further discussion of the question is reserved for the final report.

It was found that a varying quantity of water (usually about 2 per cent) could only be driven off at a very high temperature, but as yet, no simple molecular ratio between this water and the compound has been found. The material was dried at 100° C. The action of this thomsonite before the blowpipe is entirely normal.

The thomsonite of Table Mountain was first identified, through a quantitative analysis, by Carlton H. Hand, at the time a student, now, assistant in assaying, in the School of Mines, at Golden. The analysis was never published, and has since been lost.

3. *Analcite.*

Analcite follows thomsonite in time of deposition. At the locality mentioned on North Table Mountain, its crystals are pure white or transparent, and vary in size from very small ones, to those nearly an inch in diameter. The predominating form is the common trapezohedron 2-2 (202), having its octahedral edges evenly truncated by $\frac{3}{2}$ ($\frac{3}{2}$O). The appearance of $\frac{3}{2}$ is very characteristic of the Table Mountain analcite, though the form is never prominent, and is usually represented by an exceedingly narrow line. According to Zirkel,† the form $\frac{3}{2}$ has been observed but once on analcite, viz: by Laspeyres on that from the Kerguelen islands.

* C. Rammelsberg, Mineral Chemie, 1875, p. 657.

† Naumann-Zirkel, "Elemente der Mineralogie." Leipzig, 1881.

All of this analcite examined is doubly refractive, but so irregularly that it cannot well be used in confirmation of the interesting observations of Ben-Saude,* according to whom the optical anomalies of analcite are only to be explained by the theory of tension (Spannung) within the crystal, caused by some irregularities of growth.

A second generation of analcite was observed, analogous to that of chabazite, the crystals being very small and clear. They were observed upon apophyllite.

On the eastern side of North Table Mountain, analcite is often present alone, filling small cavities completely, and developed in immense crystals in the large ones. Some crystals here were nearly two inches in diameter. The faces of such large crystals are often uneven through depressions or other irregularities bounded by faces of 2-2 (202).

On South Table Mountain analcite is more abundant than any other zeolite. Large cavities have a floor of analcite, but always in quite small crystals. Natrolite is almost invariably deposited upon it, and frequently small cracks are filled with the same mineral, associated with calcite or natrolite.

Analcite was also found in spaces between the pebbles of a conglomerate bed, not far below the basalt, the pebbles being of basic eruptive rocks.

Denver, Colorado, April, 1882.

[To be continued.]

ART. LIII.—*On a new Locality for Hayesine and its novel occurrence;* by NELSON H. DARTON.

HAYESINE has only been found heretofore, as far as I can find, at Iquique, South America, upon the western coast of Africa, and in Nova Scotia, and occurring with gypsum and some allied species, the variety generally containing soda in greater or less but no fixed proportion. I now add another locality, which is Bergen Hill. It occurs here, not with gypsum, etc., but with datholite and calcite in cavities in the trap rock. At the new railroad tunnel now in progress near Weehawken, New Jersey, when down in shaft No. 2 of the tunnel at a distance of about 1600 feet from the east face of the dike and 185 feet below the ground above, I found in examining a vein of calcite, etc., exposed on the north side, a peculiar mineral lying upon the crystals in the geode that I did not recognize for this locality. It evidently was not pectolite as the fibers were quite soft, even pulverulent. They seemed more

* Alfredo Ben-Saude, "Ueber den Analcim." in "Neues Jahrbuch für Mineralogie" etc., 1882, I, 41.

like asbestos than any other species, but still in doubt I secured all that was possible, and when arriving in New York made a chemical and physical examination of it. A preliminary blow-pipe treatment showed it to be readily fusible and when moistened with acid the characteristic green flame proved it to be a borate. The analysis yielded the following results:

		Calculated to $CaB_2O_7 + 3H_2O$.
Lime	18·39	18·42
Boracic acid	46·10	46·05
Water	35·46	35·53
Silica, Soda, Magnesia	trace	
	99·95	100·00

The traces of silica and magnesia were probably due to exterior causes, but the presence of the soda was very marked. The specific gravity was between 1·5 and 1·7. I could find but 7·3 decigrams, and as the greater part of this has been used in the examinations I have but 2·6 decigrams left; but I have reason to believe that much more may be procured by cutting into the vein for it, and besides there may be many reproductions of the same conditions under which it occurred. The form was that of acicular crystals about 4^{mm} long and very slender. They were grouped together in the form of little mats and these lay loosely upon the crystals of calcite (dog-tooth spar). These geodes were surrounded by others of datholite and enclosed in a vertical vein 2½ to 4 inches wide, partly filled with the primary forms of calcite and chlorite. The rock is quite soft and very permeable to infiltering water. Thus some borate of lime has been taken into solution under peculiar and unknown conditions and crystallized after running into the geode which held it. All these geodes are open at the top, this is directed toward the upper side of the vein, and would thus arrest and hold infiltering solutions. I intend to investigate how datholite is decomposed and borate of lime separated out of its constituents.

Laboratory, 319 Pearl street.

ART. LIV.—*Notes on the Electromagnetic Theory of Light*; by J. WILLARD GIBBS. NO. II.—*On Double Refraction in perfectly transparent Media which exhibit the Phenomena of Circular Polarization.*

1. IN the April number of this Journal,* the velocity of propagation of a system of plane waves of light, regarded as oscillating electrical fluxes, was discussed with such a degree of approximation as would account for the dispersion of colors and give Fresnel's laws of double refraction. It is the object of this paper to supplement that discussion by carrying the approximation so much further as is necessary in order to embrace the phenomena of circularly polarizing media.

2. If we imagine all the velocities in any progressive system of plane waves to be reversed at a given instant without affecting the displacements, and the system of wave-motion thus obtained to be superposed upon the original system, we obtain a system of stationary waves having the same wave-length and period of oscillation as the original progressive system. If we then reduce the magnitude of the displacements in the uniform ratio of two to one, they will be identical, at an instant of maximum displacement, with those of the original system at the same instant.

Following the same method as in the paper cited, let us especially consider the system of stationary waves, and divide the whole displacement into the *regular* part, represented by ξ, η, ζ, and the *irregular* part, represented by ξ', η', ζ', in accordance with the definitions of § 2 of that paper.

3. The *regular* part of the displacement is subject to the equations of wave-motion, which may be written (in the most general case of plane stationary waves)

$$\left.\begin{aligned} \xi &= \left(\alpha_1 \cos 2\pi \frac{u}{l} + \alpha_2 \sin 2\pi \frac{u}{l}\right) \cos 2\pi \frac{t}{p}, \\ \eta &= \left(\beta_1 \cos 2\pi \frac{u}{l} + \beta_2 \sin 2\pi \frac{u}{l}\right) \cos 2\pi \frac{t}{p}, \\ \zeta &= \left(\gamma_1 \cos 2\pi \frac{u}{l} + \gamma_2 \sin 2\pi \frac{u}{l}\right) \cos 2\pi \frac{t}{p}, \end{aligned}\right\} \quad (1)$$

where l denotes the wave-length, p the period of oscillation, u the distance of the point considered from the wave-plane passing through the origin, α_1, β_1, γ_1 the amplitudes of the displacements ξ, η, ζ in the wave-plane passing through the origin, and α_2, β_2, γ_2 their amplitudes in a wave-plane one-quarter of a

* See page 262 of this volume.

wave-length distant and on the side toward which u increases. If we also write L, M, N for the direction-cosines of the wave-normal drawn in the direction in which u increases, we shall have the following necessary relations:

$$\mathrm{L}^2+\mathrm{M}^2+\mathrm{N}^2=1, \tag{2}$$

$$u=\mathrm{L}x+\mathrm{M}y+\mathrm{N}z, \tag{3}$$

$$\mathrm{L}\alpha_1+\mathrm{M}\beta_1+\mathrm{N}\gamma_1=0, \quad \mathrm{L}\alpha_2+\mathrm{M}\beta_2+\mathrm{N}\gamma_2=0. \tag{4}$$

4. That the *irregular* part of the displacement (ξ', η', ζ') at any given point is a simple harmonic function of the time, having the same period and phase as the regular part of the displacement (ξ, η, ζ), may be proved by the single principle of superposition of motions, and is therefore to be regarded as exact in a discussion of this kind. But the further conclusion of the preceding paper (§ 4), "that the values of ξ', η', ζ' at any given point in the medium are capable of expression as linear functions of ξ, η, ζ in a manner which shall be independent of the time and of the orientation of the wave-planes and the distance of a nodal plane from the point considered, so long as the period of oscillation remains the same," is evidently only approximative, although a very close approximation. A very much closer approximation may be obtained, if we regard ξ', η', ζ', at any given point of the medium and for light of a given period, as linear functions of ξ, η, ζ and the nine differential coëfficients

$$\frac{d\xi}{dx}, \quad \frac{d\eta}{dx}, \quad \frac{d\zeta}{dx}, \quad \frac{d\xi}{dy}, \quad \text{etc.}$$

We shall write ξ, η, ζ *and diff. coëff.* to denote these twelve quantities.

From this it follows immediately that with the same degree of approximation $\dot{\xi}'$, $\dot{\eta}'$, $\dot{\zeta}'$ may be regarded, for a given point of the medium and light of a given period, as linear functions of $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$ and the differential coëfficients of $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$ with respect to the coördinates. For these twelve quantities we shall write $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$ *and diff. coëff.*

5. Let us now proceed to equate the statical energy of the medium at an instant of no velocity with its kinetic energy at an instant of no displacement. It will be convenient to estimate each of these quantities for a unit of volume.

6. The statical energy of an infinitesimal element of volume may be represented by $\sigma\,dv$, where σ is a quadratic function of the components of displacement $\xi+\xi'$, $\eta+\eta'$, $\zeta+\zeta'$. Since for

that element of volume ξ', η', ζ' may be regarded as linear functions of ξ, η, ζ *and diff. coëff.*, we may regard σ as a quadratic function of ξ, η, ζ *and diff. coëff.*, or as a linear function of the seventy-eight squares and products of these quantities. But the seventy-eight coëfficients by which this function is expressed will vary with the position of the element of volume with respect to the surrounding molecules.

In estimating the statical energy for any considerable space by the integral

$$\int \sigma dv,$$

it will be allowable to substitute for the seventy-eight coëfficients contained implicitly in σ their average values throughout the medium. That is, if we write s for a quadratic function of ξ, η, ζ, *and diff. coëff.* in which the seventy-eight coëfficients are the space-averages of those in σ, the statical energy of any considerable space may be estimated by the integral

$$\int s dv.$$

(This will appear most distinctly if we suppose the integration to be first effected for a thin slice of the medium bounded by two wave-planes.) The seventy-eight coëfficients of this function s are determined solely by the nature of the medium and the period of oscillation.

We may divide s into three parts, of which the first ($s_{,}$) contains the squares and products of ξ, η, ζ, the second ($s_{,,}$) contains the products of ξ, η, ζ with the differential coëfficients, and the third ($s_{,,,}$) contains the squares and products of the differential coëfficients. It is evident that the average statical energy of the whole medium per unit of volume is the space-average of s, and that it will consist of three parts, which are the space-averages of $s_{,}$, $s_{,,}$, and $s_{,,,}$, respectively. These parts we may call $S_{,}$, $S_{,,}$, and $S_{,,,}$. Only the first of these was considered in the preceding paper.

Now the considerations which justify us in neglecting, for an approximate estimate, the terms of s which contain the differential coëfficients of ξ, η, ζ with respect to the coördinates, will apply with especial force to the terms which contain the squares and products of these differential coëfficients. Therefore, to carry the approximation one step beyond that of the preceding paper, it will only be necessary to take account of $s_{,}$ and $s_{,,}$ and of $S_{,}$ and $S_{,,}$.

7. We may set

$$s_{,} = A\xi^2 + B\eta^2 + C\zeta^2 + E\eta\zeta + F\zeta\xi + G\xi\eta, \qquad (5)$$

where, for a given medium and light of a given period, A, B, C, E, F, G are constant.

Since the average values of

$$\sin^2 2\pi\frac{u}{l}, \quad \cos^2 2\pi\frac{u}{l}, \quad \sin 2\pi\frac{u}{l}\cos 2\pi\frac{u}{l}$$

are respectively $\frac{1}{2}$, $\frac{1}{2}$, and 0, and since at the time to be considered

$$\cos^2 2\pi\frac{t}{p}=1,$$

it will appear from inspection of equations (1) that

$$S_{,}=\tfrac{1}{2}(A\alpha_1^2+B\beta_1^2+C\gamma_1^2+E\beta_1\gamma_1+F\gamma_1\alpha_1+G\alpha_1\beta_1)$$
$$+\tfrac{1}{2}(A\alpha_2^2+B\beta_2^2+C\gamma_2^2+E\beta_2\gamma_2+F\gamma_2\alpha_2+G\alpha_2\beta_2). \qquad (6)$$

This is the first part of the statical energy of the whole medium per unit of volume

8. The second part of the statical energy of the whole medium per unit of volume ($S_{,,}$) is the space-average of $s_{,,}$, which is a linear function of the twenty-seven products of ξ, η, ζ with their differential coëfficients with respect to the coördinates. Now since

$$\xi\frac{d\xi}{dx}=\tfrac{1}{2}\frac{d(\xi^2)}{dx}, \quad \eta\frac{d\eta}{dx}=\tfrac{1}{2}\frac{d(\eta^2)}{dx}, \quad \text{etc.},$$

the space-average of such products will be zero, and they will contribute nothing to the value of $S_{,,}$. There will be nine of these products, in which the same component of displacement appears twice. The remaining eighteen products may be divided into pairs according to the letters which they contain, as

$$\eta\frac{d\zeta}{dx} \quad \text{and} \quad \zeta\frac{d\eta}{dx}.$$

A linear function of the eighteen products may also be regarded as a linear function of the sums and differences of the products in such pairs. But since

$$\eta\frac{d\zeta}{dx}+\zeta\frac{d\eta}{dx}=\frac{d(\eta\zeta)}{dx},$$

the terms of $s_{,,}$ containing such sums will contribute nothing to the value of $S_{,,}$. We have left a linear function of the nine differences

$$\eta\frac{d\zeta}{dx}-\zeta\frac{d\eta}{dx}, \quad \zeta\frac{d\xi}{dx}-\xi\frac{d\zeta}{dx}, \quad \xi\frac{d\eta}{dx}-\eta\frac{d\xi}{dx}, \quad \text{etc.},$$

(the unwritten expressions being obtained by substituting in the denominators dy and dz for dx,) which constitutes the part

of $s_{//}$ that we have to consider. $S_{//}$ is therefore a linear function of the space-averages of these nine quantities. But by (3)

$$\eta\frac{d\zeta}{dx}-\zeta\frac{d\eta}{dx}=\mathrm{L}\left(\eta\frac{d\zeta}{du}-\zeta\frac{d\eta}{du}\right),$$

and the space-average of this, at a moment of maximum displacement, is by (1)

$$\frac{2\pi\mathrm{L}}{l}(\beta_1\gamma_2-\gamma_1\beta_2).$$

By such reductions it appears that $lS_{//}$ is a linear function of the nine products of L, M, N with

$$\beta_1\gamma_2-\gamma_1\beta_2,\quad \gamma_1\alpha_2-\alpha_1\gamma_2,\quad \alpha_1\beta_2-\beta_1\alpha_2.$$

Now if we set

$$\Theta=\mathrm{L}\,(\beta_1\gamma_2-\gamma_1\beta_2)+\mathrm{M}\,(\gamma_1\alpha_2-\alpha_1\gamma_2)+\mathrm{N}\,(\alpha_1\beta_2-\beta_1\alpha_2), \qquad (7)$$

we have by (4) and (2)

$$\mathrm{L}\Theta=\beta_1\gamma_2-\gamma_1\beta_2,\quad \mathrm{M}\Theta=\gamma_1\alpha_2-\alpha_1\gamma_2,\quad \mathrm{N}\Theta=\alpha_1\beta_2-\beta_1\alpha_2. \qquad (8)$$

Therefore $lS_{//}$ is a linear function of the nine products of L, M, N with $\mathrm{L}\theta$, $\mathrm{M}\theta$, $\mathrm{N}\theta$. That is, $lS_{//}$ is the product of θ and a quadratic function of L, M and N. We may therefore write

$$\mathrm{S}_{//}=\frac{\Phi}{l}\Theta=\frac{\Phi}{l}[\mathrm{L}(\beta_1\gamma_2-\gamma_1\beta_2)+\mathrm{M}(\gamma_1\alpha_2-\alpha_1\gamma_2)+\mathrm{N}\,(\alpha_1\beta_2-\beta_1\alpha_2)], \qquad (9)$$

where Φ is a quadratic function of L, M and N, dependent, however, on the nature of the medium and the period of oscillation.

9. It will be useful to consider more closely the geometrical significance of the quantity θ. For this purpose it will be convenient to have a definite understanding with respect to the relative position of the coördinate axes.

We shall suppose that the axes of X, Y, and Z are related in the same way as lines drawn to the right, forward and upward, so that a rotation from X to Y appears clock-wise to one looking in the direction of Z.

Now if from any same point, as the origin of coördinates, we lay off lines representing in direction and magnitude the displacements in all the different wave-planes, we obtain an ellipse, which we may call the *displacement-ellipse.** Of this, one radius vector (ρ_1) will have the components α_1, β_1, γ_1, and

* This ellipse, which represents the simultaneous displacements in different parts of the field, will also represent the successive displacements at any same point in the corresponding system of progressive waves.

another (ρ_2) the components α_2, β_2, γ_2. These will belong to conjugate diameters, each being parallel to the tangent at the extremity of the other. The area of the ellipse will therefore be equal to the parallelogram of which ρ_1, and ρ_2 are two sides, multiplied by π. Now it is evident that $\beta_1\gamma_2-\gamma_1\beta_2$, $\gamma_1\alpha_2-\alpha_1\gamma_2$, $\alpha_2\beta_1-\beta_1\alpha_2$ are numerically equal to the projections of this parallelogram on the planes of the coördinate axes, and are each positive or negative according as a revolution from ρ_1 to ρ_2 appears clock-wise or counter-clock-wise to one looking in the direction of the proper coördinate axis. Hence, θ will be numerically equal to the parallelogram, that is, to the area of the displacement-ellipse divided by π, and will be positive or negative according as a revolution from ρ_1 to ρ_2 appears clock-wise or counter-clock-wise to one looking in the direction of the wave-normal. Since ρ_1 and ρ_2 are determined by displacements in planes one-quarter of a wave-length distant from each other, and the plane to which the latter relates lies on the side toward which the wave-normal is drawn, it follows that θ is positive or negative according as the combination of displacements has the character of a right-handed or a left-handed screw.

10. The kinetic energy of the medium, which is to be estimated for an instant of no displacement, may be shown as in § 7 of the former paper (page 266 of this volume) to consist of two parts, of which one relates to the regular flux $(\dot\xi, \dot\eta, \dot\zeta)$, and the other to the irregular flux $(\dot\xi', \dot\eta', \dot\zeta')$. The first, in the notation of that paper, is represented by

$$\tfrac{1}{2}\int(\dot\xi\,\mathrm{Pot}\,\dot\xi+\dot\eta\,\mathrm{Pot}\,\dot\eta+\dot\zeta\,\mathrm{Pot}\,\dot\zeta)\,dv,$$

which reduces to

$$\frac{l^2}{2\pi}\int(\dot\xi^2+\dot\eta^2+\dot\zeta^2)\,dv.$$

By substitution of the values given by equations (1), we obtain for the kinetic energy due to the regular flux in a unit of volume

$$\mathrm{T}=\frac{\pi l^2}{p^2}(\alpha_1^2+\beta_1^2+\gamma_1^2+\alpha_2^2+\beta_2^2+\gamma_2^2). \qquad (10)$$

11. The kinetic energy of the irregular part of the flux is represented by the volume-integral

$$\int\tfrac{1}{2}(\dot\xi'\,\mathrm{Pot}\,\dot\xi'+\dot\eta'\,\mathrm{Pot}\,\dot\eta'+\dot\zeta'\,\mathrm{Pot}\,\dot\zeta')\,dv.$$

Now, since $\dot\xi'$, $\dot\eta'$, $\dot\zeta'$ are everywhere linear functions of $\dot\xi$, $\dot\eta$, $\dot\zeta$ *and diff. coëff.* (see § 4), and since the integrations implied in the notation *Pot* may be confined to a sphere of which the

radius is small in comparison with a wave-length,* and since within such a sphere $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$ *and diff. coëff.* are sufficiently determined (in a linear form), by the values of the same twelve quantities at the center of the sphere, it follows that Pot $\dot{\xi}'$, Pot $\dot{\eta}'$, Pot $\dot{\zeta}$ must be linear functions of the values of ξ, η', ζ *and diff. coëff.* at the point for which the potential is sought. Hence,

$$\tfrac{1}{2}(\dot{\xi}' \text{ Pot } \dot{\xi}' + \dot{\eta}' \text{ Pot } \dot{\eta}' + \dot{\zeta}' \text{ Pot } \dot{\zeta}')$$

will be a quadratic function of $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$ *and diff. coëff.* But the seventy-eight coëfficients by which this function is expressed will vary with the position of the point considered with respect to the surrounding molecules.

Yet, as in the case of the statical energy, we may substitute the average values of these coëfficients for the coëfficients themselves in the integral by which we obtain the energy of any considerable space. The kinetic energy due to the irregular part of the flux is thus reduced to a quadratic function of $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$ *and diff. coëff.* which has constant coëfficients for a given medium and light of a given period.

The function may be divided into three parts, of which the first contains the squares and products of $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$, the second the products of $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$ with their differential coëfficients, and the third, which may be neglected, the squares and products of the differential coëfficients.

We may proceed with the reduction precisely as in the case of the statical energy, except that the differentiations with respect to the time will introduce the constant factor $\frac{4\pi^2}{p^2}$. This will give for the first part of the kinetic energy of the irregular flux per unit of volume

$$\begin{aligned} \mathrm{T}'_{\prime} = {} & \frac{2\pi^2}{p^2}(\mathrm{A}'\alpha_1^2 + \mathrm{B}'\beta_1^2 + \mathrm{C}'\gamma_1^2 + \mathrm{E}'\beta_1\gamma_1 + \mathrm{F}'\gamma_1\alpha_1 + \mathrm{G}'\alpha_1\beta_1) \\ & + \frac{2\pi^2}{p^2}(\mathrm{A}'\alpha_2^2 + \mathrm{B}'\beta_2^2 + \mathrm{C}'\gamma_2^2 + \mathrm{E}'\beta_2\gamma_2 + \mathrm{F}'\gamma_2\alpha_2 + \mathrm{G}'\alpha_2\beta_2), \end{aligned} \quad (11)$$

and for the second part of the same

$$\begin{aligned} \mathrm{T}'_{\prime\prime} &= \frac{4\pi^2\Phi'}{p^2 l}\Theta \\ &= \frac{4\pi^2\Phi'}{p^2 l}[\mathrm{L}(\beta_1\gamma_2 - \gamma_1\beta_2) + \mathrm{M}(\gamma_1\alpha_2 - \alpha_1\gamma_2) + \mathrm{N}(\alpha_1\beta_2 - \beta_1\alpha_2)], \end{aligned} \quad (12)$$

* See § 9 of the former paper. on page 268 of this volume.

where A′, B′, C′, E′, F′, G′ are constant, and Φ' a quadratic function of L, M, and N, for a given medium and light of a given period.

12. Equating the statical and kinetic energies, we have

$$S_1+S_2=T+T'_1+T'_2,$$

that is, by equations (6), (9), (10), (11), and (12),

$$\begin{aligned}
&\tfrac{1}{2}(A\alpha_1^2+B\beta_1^2+C\gamma_1^2+E\beta_1\gamma_1+F\gamma_1\alpha_1+G\alpha_1\beta_1)\\
&+\tfrac{1}{2}(A\alpha_2^2+B\beta_2^2+C\gamma_2^2+E\beta_2\gamma_2+F\gamma_2\alpha_2+G\alpha_2\beta_2)\\
&+\frac{\Phi}{l}[L(\beta_1\gamma_2-\gamma_1\beta_2)+M(\gamma_1\alpha_2-\alpha_1\gamma_2)+N(\alpha_1\beta_2-\beta_1\alpha_2)\\
&=\frac{\pi l^2}{p^2}(\alpha_1^2+\beta_1^2+\gamma_1^2+\alpha_2^2+\beta_2^2+\gamma_2^2)\\
&+\frac{2\pi^2}{p^2}(A'\alpha_1^2+B'\beta_1^2+C'\gamma_1^2+E'\beta_1\gamma_1+F'\gamma_1\alpha_1+G'\alpha_1\beta_1)\\
&+\frac{2\pi^2}{p^2}(A'\alpha_2^2+B'\beta_2^2+C'\gamma_2^2+E'\beta_2\gamma_2+F'\gamma_2\alpha_2+G'\alpha_2\beta_2)\\
&+\frac{4\pi^2\Phi'}{p^2l}[L(\beta_1\gamma_2-\gamma_1\beta_2)+M(\gamma_1\alpha_2-\alpha_1\gamma_2)+N(\alpha_1\beta_2-\beta_1\alpha_2). \quad (13)
\end{aligned}$$

If we set

$$a=\frac{A}{2\pi}-\frac{2\pi A'}{p^2},\quad b=\frac{B}{2\pi}-\frac{2\pi B'}{p^2},\quad \text{etc.}, \qquad (14)$$

and

$$\varphi=\frac{\Phi}{2\pi p}-\frac{2\pi\Phi'}{p^3}, \qquad (15)$$

the equation reduces to

$$\begin{aligned}
&a\alpha_1^2+b\beta_1^2+c\gamma_1^2+e\beta_1\gamma_1+f\gamma_1\alpha_1+g\alpha_1\beta_1\\
&+a\alpha_2^2+b\beta_2^2+c\gamma_2^2+e\beta_2\gamma_2+f\gamma_2\alpha_2+g\alpha_2\beta_2\\
&+\frac{2p\varphi}{l}[L(\beta_1\gamma_2-\gamma_1\beta_2)+M(\gamma_1\alpha_2-\alpha_1\gamma_2)+N(\alpha_1\beta_2-\beta_1\alpha_2)]\\
&=\frac{l^2}{p^2}(\alpha_1^2+\beta_1^2+\gamma_1^2+\alpha_2^2+\beta_2^2+\gamma_2^2), \qquad (16)
\end{aligned}$$

where a, b, c, e, f, g are constant, and φ a quadratic function of L, M, N, for a given medium and light of a given period.

13. Now this equation, which expresses a relation between the constants of the equations of wave-motion (1), will apply, with those equations, not only to such vibrations as actually take place, but also to such as we may imagine to take place under the influence of constraints determining the type of vibration. The free or unconstrained vibrations, with which alone we are concerned, are characterized by this, that infinitesimal variations (by constraint) of the type of vibration,

that is, of the ratios of the quantities $\alpha_1, \beta_1, \gamma_1, \alpha_2, \beta_2, \gamma_2$, will not affect the period by any quantity of the same order of magnitude.* These variations must however be consistent with equations (4), which require that

$$\mathrm{L}d\alpha_1+\mathrm{M}d\beta_1+\mathrm{N}d\gamma_1=0, \quad \mathrm{L}d\alpha_2+\mathrm{M}d\beta_2+\mathrm{N}d\gamma_2=0. \qquad (17)$$

Hence, to obtain the conditions which characterize free vibration, we may differentiate equation (16) with respect to $\alpha_1, \beta_1, \gamma_1, \alpha_2, \beta_2, \gamma_2$, regarding all other letters as constant, and give to $d\alpha_1, d\beta_1, d\gamma_1, d\alpha_2, d\beta_2, d\gamma_2$, such values as are consistent with equations (17). Now $d\alpha_1, d\beta_1, d\gamma_1$, are independent of $d\alpha_2, d\beta_2, d\gamma_2$, and for either three variations, values proportional either to $\alpha_1, \beta_1, \gamma_1$, or to $\alpha_2, \beta_2, \gamma_2$, are possible. If, then, we differentiate equation (16) with respect to $\alpha_1, \beta_1, \gamma_1$, and substitute first $\alpha_1, \beta_1, \gamma_1$, and then $\alpha_2, \beta_2, \gamma_2$, for $d\alpha_1, d\beta_1, d\gamma_1$, and also differentiate with respect to $\alpha_2, \beta_2, \gamma_2$, with similar substitutions, we shall obtain all the independent equations which this principle will yield.

If we differentiate with respect to $\alpha_1, \beta_1, \gamma_1$, and write $\alpha_1, \beta_1, \gamma_1$ for $d\alpha_1, d\beta_1, d\gamma_1$, we obtain

$$\begin{aligned} &a\alpha_1^2+b\beta_1^2+c\gamma_1^2+e\beta_1\gamma_1+f\gamma_1\alpha_1+g\alpha_1\beta_1 \\ &+\frac{p\varphi}{l}[\mathrm{L}(\beta_1\gamma_2-\gamma_1\beta_2)+\mathrm{M}(\gamma_1\alpha_2-\alpha_1\gamma_2)+\mathrm{N}(\alpha_1\beta_2-\beta_1\alpha_2)] \\ &=\frac{l^2}{p^2}(\alpha_1^2+\beta_1^2+\gamma_1^2). \end{aligned} \qquad (18)$$

If we differentiate with respect to $\alpha_1, \beta_1, \gamma_1$, and write $\alpha_2, \beta_2, \gamma_2$ for $d\alpha_1, d\beta_1, d\gamma_1$, we obtain

$$\begin{aligned} &2a\alpha_1\alpha_2+2b\beta_1\beta_2+2c\gamma_1\gamma_2+e(\beta_1\gamma_2+\gamma_1\beta_2)+f(\gamma_1\alpha_2+\alpha_1\gamma_2) \\ &+g(\alpha_1\beta_2+\beta_1\alpha_2)=\frac{2l^2}{p^2}(\alpha_1\alpha_2+\beta_1\beta_2+\gamma_1\gamma_2). \end{aligned} \qquad (19)$$

If we differentiate with respect to $\alpha_2, \beta_2, \gamma_2$, and write $\alpha_2, \beta_2, \gamma_2$ for $d\alpha_2, d\beta_2, d\gamma_2$, we obtain

$$\begin{aligned} &a\alpha_2^2+b\beta_2^2+c\gamma_2^2+e\beta_2\gamma_2+f\gamma_2\alpha_2+g\alpha_2\beta_2 \\ &+\frac{p\varphi}{l}[\mathrm{L}(\beta_1\gamma_2-\gamma_1\beta_2)+\mathrm{M}(\gamma_1\alpha_2-\alpha_1\gamma_2)+\mathrm{N}(\alpha_1\beta_2-\beta_1\alpha_2)] \\ &=\frac{l^2}{p^2}(\alpha_2^2+\beta_2^2+\gamma_2^2). \end{aligned} \qquad (20)$$

The equation derived by differentiating with respect to $\alpha_2, \beta_2, \gamma_2$, and writing $\alpha_1, \beta_1, \gamma_1$ for $d\alpha_2, d\beta_2, d\gamma_2$, is identical with (19). We should also observe that equations (18) and (20) by addi-

* Compare § 11 of the former paper, page 270 of this volume.

tion give equation (16), which therefore will not need to be considered in addition to the last three equations.

14. The geometrical signification of our equations may now be simplified by a suitable choice of the position of the origin of coördinates, which is as yet wholly arbitrary.

We shall hereafter suppose that the origin is placed in a plane of maximum or minimum displacement,* if such there are. In the case of circular polarization, in which the displacements are everywhere equal, its position is immaterial. The lines ρ_1 and ρ_2, of which $\alpha_1, \beta_1, \gamma_1$ and $\alpha_2, \beta_2, \gamma_2$ are respectively the components, will now be the semi-axes of the displacement-ellipse, and therefore at right angles. (See § 9.) The case of circular polarization will not constitute any exception. Hence,

$$\alpha_1\alpha_2+\beta_1\beta_2+\gamma_1\gamma_2=0. \qquad (21)$$

and by § 9,

$$\Theta=\mathrm{L}(\beta_1\gamma_2-\gamma_1\beta_2)+\mathrm{M}(\gamma_1\alpha_2-\alpha_1\gamma_2)+\mathrm{N}(\alpha_1\beta_2-\beta_1\alpha_2)=\pm\rho_1\rho_2, \qquad (22)$$

where we are to read + or − in the last member according as the system of displacements has the character of a right-handed or a left-handed screw.

15. Equation (19) is now reduced to the form

$$2a\alpha_1\alpha_2+2b\beta_1\beta_2+2c\gamma_1\gamma_2+e(\beta_1\gamma_2+\gamma_1\beta_2)+f(\gamma_1\alpha_2+\alpha_1\gamma_2)+g(\alpha_1\beta_2+\beta_1\alpha_2)=0, \qquad (23)$$

which has a very simple geometrical signification. If we consider the ellipsoid

$$ax^2+by^2+cz^2+eyz+fzx+gxy, \qquad (24)$$

and especially its central section by a plane parallel to the planes of the wave-system which we are considering, it will easily appear that the equation

$$2ax_1x_2+2by_1y_2+2cz_1z_2+e(y_1z_2+z_1y_2)+f(z_1x_2+x_1z_2)+g(x_1y_2+y_1x_2)=0$$

will hold of any two points x_1, y_1, z_1 and x_2, y_2, z_2 which belong to conjugate diameters of this central section. Therefore equation (23) expresses that the displacements $\alpha_1, \beta_1, \gamma_1$ and $\alpha_2, \beta_2, \gamma_2$ are parallel to conjugate diameters of the central section of the ellipsoid (24) by a wave-plane. But since the displacements $\alpha_1, \beta_1, \gamma_1$ and $\alpha_2, \beta_2, \gamma_2$ are also at right angles to each other, it follows that they are parallel to the axes of the central section of the ellipsoid (24) by a wave-plane. That is:—

* The reader will perceive that an earlier limitation of the position of the origin by a supposition of this nature, involving a limitation of the values of $\alpha_1, \beta_1, \gamma_1, \alpha_2, \beta_2, \gamma_2$, would have been embarrassing in the operations of the last paragraph.

The axes of the displacement-ellipse coincide in direction with those of a central section of the ellipsoid (24) by a wave-plane.

16. If we write U_1, U_2 for the reciprocals of the semi-axes of the central section of the ellipsoid (24) by a wave-plane, U_1 being the reciprocal of the one to which the displacement α_1, β_1, γ_1 is parallel, we have

$$a\alpha_1^2+b\beta_1^2+c\gamma_1^2+e\beta_1\gamma_1+f\gamma_1\alpha_1+g\alpha_1\beta_1=U_1^2(\alpha_1^2+\beta_1^2+\gamma_1^2), \quad (25)$$

as is at once evident, if we substitute the coördinates of an extremity of the axis, for the proportional quantities α_1, β_1, γ_1. So also

$$a\alpha_2^2+b\beta_2^2+c\gamma_2^2+e\beta_2\gamma_2+f\gamma_2\alpha_2+g\alpha_2\beta_2=U_2^2(\alpha_2^2+\beta_2^2+\gamma_2^2). \quad (26)$$

If we write V for the velocity of propagation of the system of progressive waves corresponding to the system of stationary waves which we have been considering, we shall have

$$V=\frac{l}{p}. \quad (27)$$

By equations (22), (25), and (26), equations (18) and (20) are reduced to the form

$$U_1^2\rho_1^2\pm\frac{\varphi}{V}\rho_1\rho_2=V^2\rho_1^2, \quad U_2^2\rho_2^2\pm\frac{\varphi}{V}\rho_1\rho_2=V^2\rho_2^2, \quad (28)$$

where we are to read + or − according as the disturbance has the character of a right-handed or a left-handed screw. In a progressive system of waves, when the combination of displacements has the character of a right-handed screw, the rotations will be such as appear clock-wise to the observer, who looks in the direction opposite to that of the propagation of light. We shall call such a ray *right-handed*.

We may here observe that in case $\varphi=0$ the solution of these equations is very simple. We have necessarily either $\rho_2=0$ and $V^2=U_1^2$, or $\rho_1=0$ and $V^2=U_2^2$. In this case, the light is linearly polarized, and the directions of oscillation and the velocities of propagation are given by Fresnel's law. Experiment has shown that this is the usual case. We wish, however, to investigate the case in which φ does not vanish. Since the term containing φ arises from the consideration of those quantities which it was allowable to neglect in the first approximation, we may assume that φ is always very small in comparison with V^3, U_1^3, or U_2^3.

17. Equations (28) may be written

$$V^2-U_1^2=\pm\frac{\varphi}{V}\frac{\rho_2}{\rho_1}, \quad V^2-U_2^2=\pm\frac{\varphi}{V}\frac{\rho_1}{\rho_2}. \quad (29)$$

By multiplication we obtain

$$V^2(V^2-U_1^2)(V^2-U_2^2)=\varphi^2. \qquad (30)$$

Since φ is a very small quantity, it is evident from inspection of this equation that it will admit three values of V^2, of which one will be a very little greater than the greater of the two quantities U_1^2 and U_2^2, another will be a very little less than the less of the same two quantities, and the third will be a very small quantity. It is evident that the values of V^2 with which we have to do are those which differ but little from U_1^2 and U_2^2.*

For the numerical computation of V, when U_1, U_2, and φ are known numerically, we may divide the equation by V^2, and then solve it as if the second member were known. This will give

$$V^2=\frac{U_1^2+U_2^2}{2}\pm\sqrt{\frac{\varphi^2}{V^2}+\frac{(U_1^2-U_2^2)^2}{4}}. \qquad (31)$$

By substituting U_1U_2 for V^2 in the second member, we may obtain a close approximation to the two values of V^2. Each of the values obtained may be improved by substitution of that value for V^2 in the second member of the equation.

For either value of V^2, we may easily find the ratio of ρ_1 to ρ_2, that is, the ratio of the axes of the displacement-ellipse, from one of equations (29), or from the equation

$$\frac{\rho_2^2}{\rho_1^2}=\frac{V^2-U_1^2}{V^2-U_2^2} \qquad (32)$$

obtained by combining the two.

In equations (29), we are to read + or − in the second members, according as the ray is right-handed or left-handed. (See § 16.) It follows that if the value of φ is positive, the greater velocity will belong to a right-handed ray, and the smaller to a left-handed, but if the value of φ is negative, the opposite is the case. Except when $\varphi=0$, and the polarization is linear, there will be one right-handed and one left-handed ray for any given wave-normal and period.

18. When $U_1=U_2$, equations (29) give

$$\rho_1=\rho_2, \quad V^2=U^2\pm\frac{\varphi}{V},$$

* We should not attribute any physical significance to the third value of V^2. For this value would imply a wave-length very small in comparison with the length of ordinary waves of light, and with respect to which our fundamental assumption that the wave-length is very great in comparison with the distances of contiguous molecules would be entirely false. Our analysis, therefore, furnishes no reason for supposing that any such velocities are possible for the propagation of electrical disturbances.

where U represents the common value of U_1 and U_2. The polarization is therefore circular. The converse is also evident from equations (29), viz: that a ray can be circularly polarized only when the direction of its wave-normal is such that $U_1 = U_2$. Such a direction, which is determined by a circular section of the ellipsoid (24) precisely as an optic axis of a crystal which conforms to Fresnel's law of double refraction, may be called an optic axis, although its physical properties are not the same as in the more ordinary case.* If we write V_R and V_L, respectively, for the wave-velocities of the right-handed and left-handed rays, we have

$$V_R^2 = U^2 + \frac{\varphi}{V_R}, \quad V_L^2 = U^2 - \frac{\varphi}{V_L}; \tag{33}$$

whence

$$V_R^2 - V_L^2 = \varphi\left(\frac{1}{V_R} + \frac{1}{V_L}\right) = \varphi\frac{V_R + V_L}{V_R V_L},$$

and

$$V_R - V_L = \frac{\varphi}{V_R V_L}. \tag{34}$$

The phenomenon best observed with respect to an optic axis is the rotation of the plane of linearly polarized light. If we denote by θ the amount of this rotation per unit of the distance traversed by the wave-plane, regarding it as positive when it appears clock-wise to the observer, who looks in the direction opposite to that of the propagation of the light,† we have

$$\theta = \frac{\pi}{p}\left(\frac{1}{V_L} - \frac{1}{V_R}\right), \tag{35}$$

By the preceding equation, this reduces to

$$\theta = \frac{\pi\varphi}{pV_R^2 V_L^2}. \tag{36}$$

*Our experimental knowledge of circularly or elliptically polarizing media is confined to such as are optically either isotropic or uniaxial. The general theory of such media, embracing the case of two optic axes, has however been discussed by Professor von Lang. (*Theorie der Circularpolarization*, Sitz.-Ber. Wiener Akad., vol. lxxv. p. 719.) The general results of the present paper, although derived from physical hypotheses of an entirely different nature, are quite similar to those of the memoir cited. They would become identical, the writer believes, by the substitution of a constant for $\frac{p\varphi}{l}$ or $\frac{\varphi}{V}$ in the equations of this paper. [See especially equations (18), (20), (28).]

That a complete discussion of the subject on any theory must include the case of biaxial media having the property of circular or elliptical polarization, is evident from the consideration that it must at least be possible to produce examples of such media artificially. An isotropic or uniaxial crystal may be made biaxial by pressure. If it has the property of circular and elliptic polarization, that property cannot be wholly destroyed by the application of small pressures.

†When the rotation of the plane of polarization appears clock-wise to the observer, it has the character of a *left-handed* screw. But the circularly polarized ray to which V_R relates, the rotation of which also appears clock-wise to the observer, has the character of a *right-handed* screw.

Without any appreciable error, we may substitute U^4 for $V_R^2 V_L^2$, which will give*

$$\theta=\frac{\pi\varphi}{pU^4}. \tag{37}$$

19. Since these equations involve unknown functions of the period, they will not serve for an exact determination of the relation between θ and the period. For a rough approximation, however, we may assume that the manner in which the general displacement in any small part of the medium distributes itself among the molecules and intermolecular spaces is independent of the period, being determined entirely by the values of ξ, η, ζ, and their differential coëfficients with respect to the coördinates.† For a fixed direction of the wave-normal, Φ and Φ' will then be constant. Now equations (15) and (36) give

$$\theta=\frac{\Phi}{2p^2V_R^2V_L^2}-\frac{2\pi^2\Phi'}{p^4V_R^2V_L^2} \tag{38}$$

To express this result in terms of the quantities directly observed, we may use the equations

$$p=\frac{\lambda}{k},\quad V_R=\frac{k}{n_R},\quad V_L=\frac{k}{n_L},\quad U=\frac{k}{n},$$

where k denotes the velocity of light *in vacuo*, λ the wave-length *in vacuo* of the light employed, n_R, n_L the absolute indices of refraction of the two rays, and n the index for the optic axis as derived from the ellipsoid (24) by Fresnel's law. We thus obtain

$$\theta=\frac{\Phi n_R^2 n_L^2}{2k^2\lambda^2}-\frac{2\pi^2\Phi' n_R^2 n_L^2}{\lambda^4} \tag{39}$$

In the case of uniaxial crystals, the direction of the optic axis is fixed. We may therefore write

$$\theta=n_R^2 n_L^2\left(\frac{K}{\lambda^2}+\frac{K'}{\lambda^4}\right), \tag{40}$$

regarding K and K′ as constants. If we had used equation (37), we should have had the factor n^4 instead of $n_R^2 n_L^2$.

* The degree of accuracy of this substitution may be shown as follows. By (33)

$$V_R(V_R^2-U^2)=V_L(U^2-V_L^2),$$

whence

$$V_R^3+V_L^3=(V_R+V_L)U^2,$$
$$V_R^2-V_RV_L+V_L^2=U^2,$$
$$V_RV_L=U^2-(V_R-V_L)^2.$$

† Compare § 12 of the former paper, on page 270 of this volume.

Since this factor varies but slowly with λ, it may be neglected, if its omission is compensated in the values of K and K′. The formula being only approximative, such a simplification will not necessarily render it less accurate.

20. But without any such assumption as that contained in the last paragraph, we may easily obtain formulæ for the experimental determination of Φ and Φ' for the optic axis of an uniaxial crystal. Considerations analogous to those of § 13 of the former paper (page 271 of this volume), show that in differentiating equation (39) we may regard Φ and Φ' as constant, although they may actually vary with λ. This equation may be written

$$\frac{\theta\lambda^2}{n^4}=\frac{\Phi}{2k^2}-\frac{2\pi^2\Phi'}{\lambda^2} \qquad (41).$$

Therefore,

$$\frac{d\left(\frac{\theta\lambda^2}{n^4}\right)}{d\left(\frac{1}{\lambda^2}\right)}=-2\pi^2\Phi'. \qquad (42).$$

When Φ' has been determined by this equation, Φ may be found from the preceding.

21. If we wish to represent φ geometrically, like U_1 and U_2, we may construct the surfaces

$$Ax^2+By^2+Cz^2+Eyz+Fzx+Gxy=\pm 1, \qquad (43).$$

the coëfficients A, B, etc., being the same by which φ is expressed in terms of L^2, M^2, etc. The numerical value of φ, for any direction of the wave-normal, will thus be represented by the square of the reciprocal of the radius vector of the surface drawn in the same direction. The positive or negative character of φ must be separately indicated. There are here two cases to be distinguished. If the sign of φ is the same in all directions, the surface will be an ellipse, and we have only to know whether all the values of φ are to be taken positively or all negatively. But if φ is positive for some directions and negative for others, the surface will consist of two conjugate hyperboloids, to one of which the positive, and to the other the negative values belong.

22. The manner in which the ellipsoid (24) may be partially determined by the relatjons of symmetry which the medium may possess, has been sufficiently discussed in the former paper.

With respect to the quantity φ, and the surfaces which determine it, the following principle is of fundamental importance. If one body is identical in its internal structure with the image by reflection of another, the values of φ in corres-

ponding lines in the two bodies will be numerically equal but have opposite signs.*

It follows that if a body is identical in internal structure with its own image by reflection, the value of φ (if not zero for all directions) must be positive for some directions and negative for others. Moreover, the above described surface by which φ is represented must consist of two conjugate hyperboloids, of which one is identical in form with the image by reflection of the other. This requires that the hyperboloids shall be right cylinders with conjugate rectangular hyperbolas for bases. A crystal characterized by such properties will belong to the tetragonal system. Since $\varphi=0$ for the optic axis, it would be difficult to distinguish a case of this kind from an ordinary uniaxial crystal, unless the ellipsoid (24) should approach very closely to a sphere.†

It is only in the very limited case described in the last paragraph that a medium which is identical in its internal structure with its image by reflection can have the property of circular or elliptic polarization. To media which are unlike their images by reflection, and have the property of circular polarization, we may apply the following general principles.

If the medium has any axis of symmetry, the ellipsoid or hyperboloids which represent the values of φ will have an axis in the same direction. If the medium after a revolution of less than 180° about any axis is equivalent to the medium in its first position, the ellipsoid or hyperboloids will have an axis of revolution in that direction.

23. The laws of the propagation of light in plane waves, which have thus been derived from the single hypothesis that the disturbance by which light is transmitted consists of solenoidal electrical fluxes, and which apply to light of different colors and to the most general case of perfectly transparent and sensibly homogeneous media not subject to magnetic action,‡ are essentially those which are generally received as

* The necessity of the opposite signs will perhaps appear most readily from the consideration that the direction of rotation of the plane of polarization must be opposite in the two bodies.

† There is no difficulty in conceiving of the constitution of a body which would have the properties described above. Thus, we may imagine a body with molecules of a spiral form, of which one-half are right-handed and one-half left-handed, and we may suppose that the motion of electricity is opposed by a less resistance within them than without. If the axes of the right-handed molecules are parallel to the axis of X, and those of the left-handed molecules to the axis of Y, their effects would counterbalance one another when the wave-normal is parallel to the axis of Z. But when the wave-normal (of a beam of linearly polarized light), is parallel to the axis of X, the left-handed molecules would produce a left-handed (negative) rotation of the plane of polarization, the right-handed molecules having no effect; and when the wave-normal is parallel to the axis of Y, the reverse would be the case.

‡ The rotation of the plane of polarization which is produced by magnetic action has been discussed by Maxwell (*Treatise on Electricity and Magnetism*, vol. ii. Chap. XXI), and by Rowland (Amer. Journ. Math., vol. iii. p. 107).

embodying the results of experiment. In no particular, so far as the writer is aware, do they conflict with the results of experiment, or require the aid of auxiliary and forced hypotheses to bring them into harmony therewith.

In this respect, the electromagnetic theory of light stands in marked contrast with that theory in which the properties of an elastic solid are attributed to the ether,—a contrast which was very distinct in Maxwell's derivation of Fresnel's laws from electrical principles, but becomes more striking as we follow the subject farther into its details, and take account of the want of absolute homogeneity in the medium, so as to embrace the phenomena of the dispersion of colors and circular and elliptical polarization.

ART. LV. — *New Phyllopod Crustaceans from the Devonian of Western New York;* by JOHN M. CLARKE, Smith College. With a Plate (unnumbered.)

Estheria pulex, n. sp. Plate, fig. 4.

IN examining some fragments of soft, olive-colored shale from near the base of the Hamilton proper, in Miles' Gully, Hopewell, Ontario Co., I have detected the above representative of this extremely interesting genus. The little carapaces are never more than $\frac{2}{3}^{mm}$ in width and $\frac{1}{2}^{mm}$ in length, and may be described as having the ventral margin nearly semi-circular, the beak central or very slightly anterior, hinge line sloping laterally. The surface is marked by six, or in the largest seven, concentric ridges which are very broad with narrow intervening furrows. There appears to be no more elaborate sculpturing of the carapaces than Jones has figured for his species *E. membranacea*, which is the simplest of any as yet noticed.

It is interesting to notice that this *Estheria*, the first ever found below the Trias in America and nowhere at so low an horizon as this, resembles in its sub-central beak, its outline and surface markings, this species just referred to, *E. membranacea* Jones, from the Old Red of Caithness, while all others figured by that author (Mon. Esth. Paleontogr. Soc., vol. xviii) are from higher horizons, have the beak anterior, and the outline of the carapace more nearly sub-trigonal.

All recent *Estheriæ* are found in fresh, or, in possible cases, brackish waters. In some general remarks in this connection Jones has said that "seeing that *Estheriæ* appear in pools and ditches of rain-water, it is not unlikely that pools of fresh water temporarily formed on a flat sea-shore may have been inhabited.

by *Estheriæ*, destined to be quickly buried in the first wind-drift of sand on the return of high tide." We can not prove from this species, *E. pulex*, the presence of fresh-water deposits in the Hamilton, but the evidence is fairly in favor of brackish water pools, guarded from the action of the waves of the open ocean and depositing a smooth muddy bottom. Associated with these clannish little fellows are undescribed species of *Beyrichia*, *Leperditia*, *Entomis*, with a species of *Discina* not identified, and this association, omitting the *Discina*, is not an impossible one for such a brackish water pond. Even the *Discina* itself is not a serious objection to it, as I have found but a single example, which may have been washed in either as a dead shell, or as a live one, and if the latter, may have soon yielded to its unfavorable environment and died, or have adapted itself to the change and have lived on in an abnormal condition, as this specimen seems to prove.

Spathiocaris, n. g. ($\sigma\pi\acute{\alpha}\theta\eta$=a spathe.) Plate, figs. 1, 2, 3.

Carapace in one piece (?), oblong-elliptical; dimensions when normal, length : width : : 3 : 2. Anterior and posterior marginal curvature of the same value except near the sides of the fissure on the posterior extremity where for a short distance the outline becomes rectilinear. The central portion of the carapace elevated, the apical point being nearly a focus of the ellipse, and from this point starts a cleft extending backward and regularly widening to the posterior margin. No evidence of dorsal suture except in the fact that when flattened laterally, as many specimens are, the line of folding is usually straight from apex to anterior margin, but there is no external mark of a commissure in the ornamentation lines on the surface. It has for several years been a matter of some doubt to myself, whether this fossil should be looked upon as crustacean, which I now believe it to be, or some new form of Discinoid brachiopod which it very closely resembles, but my reasons for believing it the former lie in the fact that while I have in my possession thirty specimens, all that have as yet been found and all from a layer only a few inches in thickness, they show a great variation in size from a length of four to sixty millimeters, a fragment of an unusually large individual showing a probable length of even eighty or ninety millimeters, which is not a fact to expect from the Discinoid brachiopods; and, moreover, every specimen that is well preserved shows the cleft in the carapace, so that among them all there is no evidence of the ventral or non-fissured valve which we should expect to find if the animal had been brachiopodous. The genus *Discinocaris* described by Woodward from the Moffat shales of Dumfriesshire (Quart. Jour. Geol. Soc., vol. xxii), agrees with *Spathiocaris* in the

anchylosis of the lateral valves and its wide, wedge-shaped cleft, but differs in the presence of the "rostrum" or plate acting as another valve to cover the cleft, and also in its more nearly circular outline.

The ornamentation of the surface of the carapace in this species, *S. Emersonii*, n. sp., consists of low concentric ridges which never lose their continuity, but contiguous ridges are more closely appressed on the sides than at the extremities of the valves. At the edges of the cleft these lines show a tendency to a retral bending.

Radiating lines from the apex of the cleft to the margin cover the anterior portion of the carapace and give to this part a strong decussate sculpturing which is rarely noticeable along the margins of the cleft. I am not satisfied that I have seen the abdominal arthromeres of this species, though it will be only a matter of time for their detection.

The geological horizon in which this occurs, the Portage, is usually regarded as barren of fossils in New York, but is showing under careful scrutiny many facts of paleontological interest and bids fairly especially in the direction of the phyllopod crustacea.

From Naples, Ontario Co., N. Y.

Fig. 1. *Spathiocaris Emersonii*, shows the carapace free from compression but with an unusually central apex.—Fig. 2. The same, young.—Fig. 3. The same, showing by lateral compression the usual position of the apex and length of the abdominal cleft, as well as the position of the possible dorsal suture.

Lisgocaris, n. g. (λίσγος=a shovel.)

Carapace in one piece, without evidence of dorsal suture. Periphery sub-pentagonal, lateral edges parallel, making sharp angles with the two anterior edges. Anterior edges re-entrantly curved and meeting in the axis of the carapace. As in the genus *Spathiocaris*, there is an abdominal cleft beginning centrally and at the highest point of the carapace, which is considerably elevated, and widening to the posterior margin.

This species, *L. Lutheri*, has the surface of the carapace concentrically marked with fine, crowded, impressed lines. No evidence of abdominal arthromeres. This is a very delicate form measuring three by two millimeters, which has been found near the base of the Hamilton proper in the same horizon as *Estheria pulex*. It belongs to the apus type of the phyllopods with *Pellocaris* Salter, *Discinocaris* Woodward, and *Spathiocaris*.

Northampton, Mass.

Art. LVI.—*An Organ-Pipe Sonometer*; by W. LeConte Stevens.*

While using the sonometer in illustrating the laws of vibration of stretched cords and the nature of musical scales, it has been found desirable to have an instrument on which division-marks were properly arranged to furnish the operator the means of contrasting the scale of equal temperament with the true natural scale, and thus showing to some extent the error of the ordinary keyed instruments. In demonstrating the laws of vibration of columns of air, moreover, it is not always easy to obtain the successive notes of the harmonic series from a single pipe. If the fundamental is pure and strong, either the upper harmonics are unattainable or several are attained at the same moment, and the untrained ear fails to single out the one to which attention is invited. If a single standard of pitch be kept at hand for comparison, the auditor must be practiced in estimating musical intervals; hence a tuning fork alone is not sufficient for most persons. It occurred to me that the union of sonometer with organ pipe in a single instrument would be attended with some advantages, particularly in connection with the exhibition of Bernoulli's laws. The following device has been found very satisfactory.

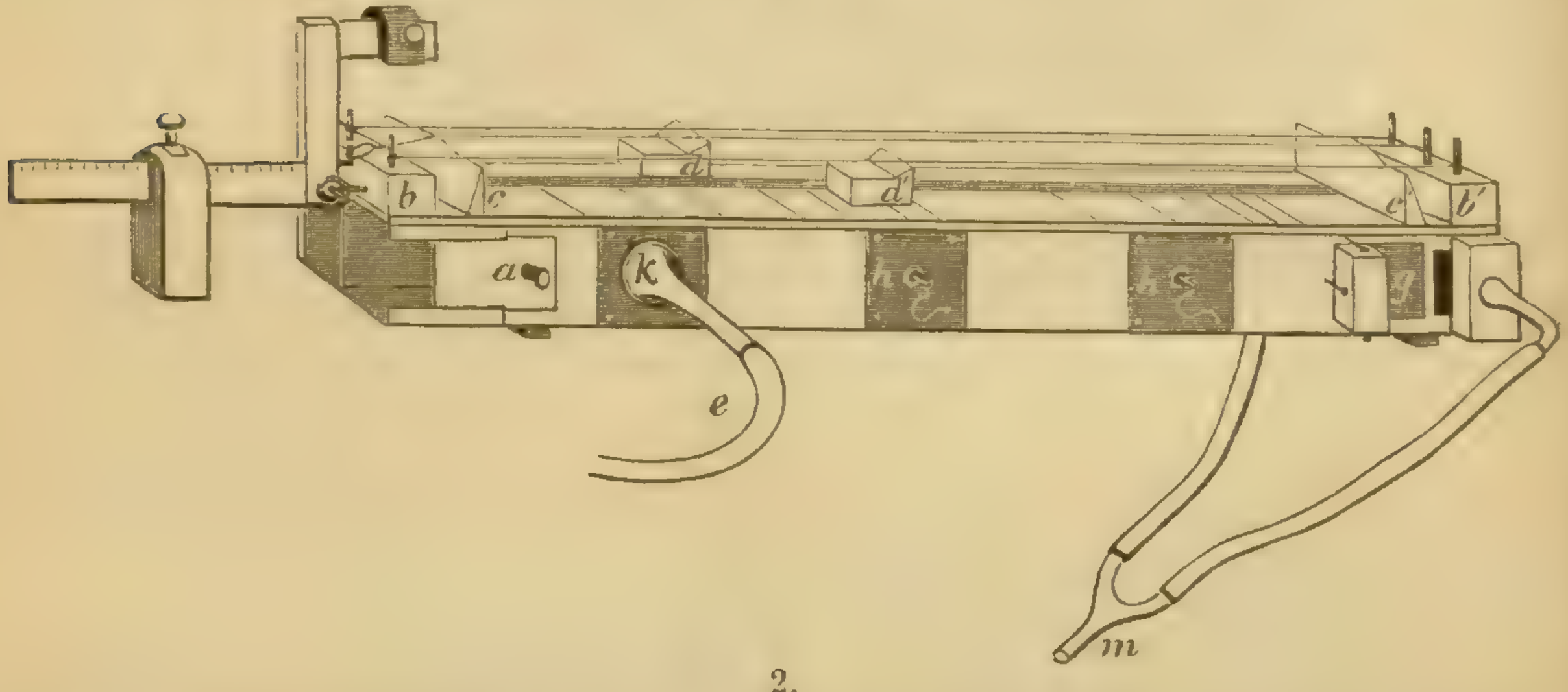
The resonance-box consists of a double organ pipe of spruce, which is rested horizontally on the lecture table. The two embouchures are on opposite sides, one being turned toward the operator, as in fig. 1. The air-blast, from either the lungs or a pair of bellows, may be forced into either one or both pipes at will through gum tubes. The interior dimensions of each pipe are 52^{mm} by 62^{mm}, while the length is adjusted to give as fundamental note, C, 132 vibrations per second. At the open end of one pipe is a sliding plate (a) by which it may be thrown out of unison with the other, thus producing beats. A stop may be thrust, by means of its handle, half way into one of the pair, converting it at will into a stopped pipe whose fundamental is the same as that of the open pipe of double its length.

The upper wall consists of a single plate of spruce, 5^{mm} thick, that forms the sound-board of the sonometer. Firmly fixed at each end is a block of hard wood (b, b') into which piano pins are driven for the attachment of three steel wires which pass over the fixed bridges (c, c'). The latter are exactly 1^{m} apart, in contact with the ends of a strip of wood divided at each edge into millimeters, and occupying the middle of the sound-board. This strip not only serves as a guide for the movable bridges

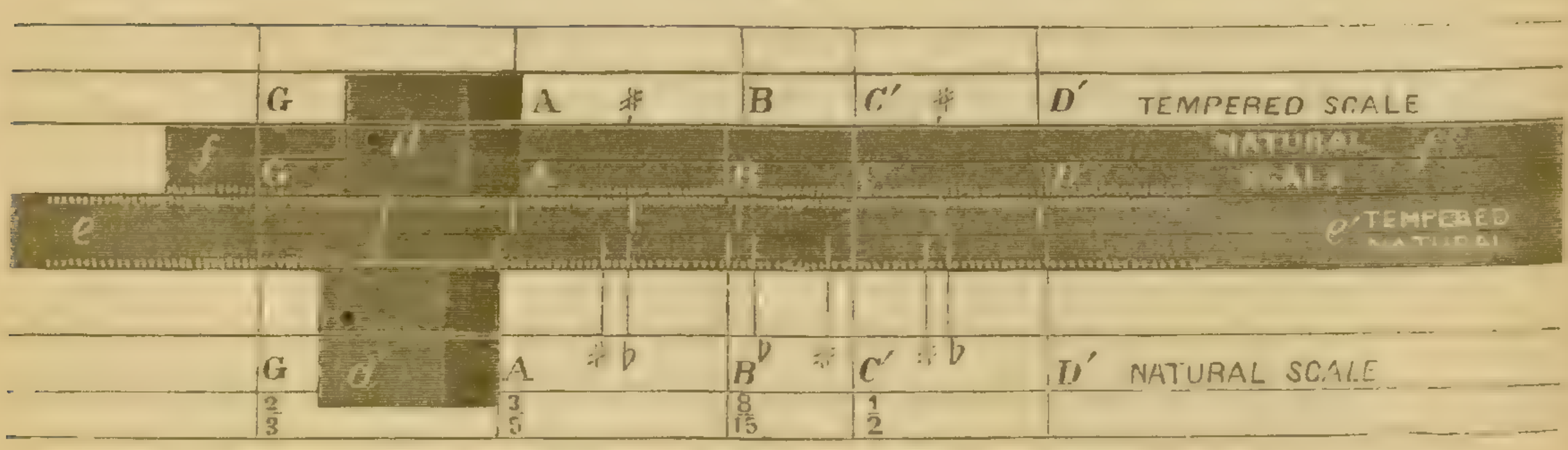
* Presented before the New York Academy of Sciences, May 1st, 1882.

(d, d') but makes it easy to mark off the division lines at their proper places. A longitudinal line divides its surface into two equal parts; that on the side toward the operator is marked off so as to give cord-lengths for the natural scale, by changing the fractions $\frac{8}{9}$, $\frac{4}{5}$, $\frac{3}{4}$, etc., into decimals. The results are indicated, correct to three places, on the millimeter scale. Three octaves in succession are thus marked off; the lines for the first octave

1.



2.



extending across to the edge of the sound-board, as in fig. 2, which represents a part of the instrument viewed from above. By multiplying each of these lengths successively by $1\frac{3}{20}\frac{5}{8}$ and $1\frac{28}{35}$ we obtain cord-lengths for the chromatic intervals of the natural scale. These are marked off for two octaves, the lines extending half way to the edge. The other side of the central strip (e e', fig. 2) is marked off to give cord-lengths for the successive semitone intervals of the scale of equal temperament. These are easily calculated with the aid of a table of logarithms; for since the twelve intervals of this scale are equal, the successive vibration-numbers form a geometric series, in which the common ratio is

$$r = \sqrt[12]{2} = 1{\cdot}05946.$$

The reciprocal of this is the ratio for cord-lengths, and is

$$r' = {\cdot}94388.$$

Thus, the cord-length for C being one meter, we have for C♯, $l=944^{mm}$; for D, $l=891^{mm}$, etc. Two octaves are thus marked off for the scale of equal temperament, with twelve division-lines to the octave, while on the other side are twenty-one to the octave.

Of the three wires, the two outer ones are kept permanently unisonant, or as nearly so as possible, sounding the same note, C, as the fundamental of the organ-pipes. That in the middle terminates at the left in a stiff ring, so as to be detached in a moment from the hook against which it is ordinarily kept pulled. The ring may then be attached in like manner to a bent lever, such as is employed with the sonometers constructed by Mr. Ritchie, to show the law of variation in tension.

Since the tension of the outer wires is kept constant, each division-mark in both natural and tempered scales, is distinctly labeled, as shown in fig. 2. The movable bridges are black at the front edges so as to contrast strongly with the white spruce on which they slide. Suppose the bridge d' to be adjusted so that its wire sounds E of the natural scale, while its companion, d, is adjusted to give E of the tempered scale. The difference in pitch is nearly a comma, and can be detected by a good ear. But this is additionally made visible by turning the sonometer toward the audience, and resting it on its narrow side; the difference in position of the bridges being easily detectible even when the ear fails to distinguish between the two sounds. Every note in the two scales can thus be compared in a few moments, starting with C as key note.

The necessity for temperament, and yet the unavoidable error of a tempered scale, is still better shown by taking some derived key for purposes of comparison; for example, that of G. For this purpose a separate strip (f, f', fig. 2), properly marked off, is placed at the side of the central strip, the movable bridge being grooved below to slide over it. It is prepared by marking a strip whose length is $\frac{2}{3}$ meter at distances $\frac{8}{9}$, $\frac{4}{5}$, , , , , , , , $\frac{1}{2}$, and then discarding the unmarked half. Placing the initial extremity of this scale in contact with the division-mark G of the tempered scale, which in this case sensibly coincides with that of G on the natural scale, it is seen that the second note, if correctly tuned, would be a trifle higher than tempered A, and decidedly higher than natural A; the third would be lower than tempered B, and unisonant with natural B; the fourth unisonant with C, both tempered and natural, etc. Such a strip can be constructed for each one of the derived keys employed in music, though the principle is sufficiently shown with but one.

The division-marks $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, etc., each labeled with the name of the corresponding note, C′, G′, C″, E″, G″, etc., as well

as with the figures composing the fraction, render it easy to obtain with quickness and accuracy the first ten or twelve notes of the harmonic series, besides facilitating experiments on co-vibration.

To obtain the harmonic series from the open organ-pipe, it is found convenient to modify the size of the embouchure and the diameter of the pipe. For this last purpose a piece of wood, 120^{cm} long, 6^{cm} wide, and 2^{cm} thick, is thrust into the pipe next the operator, thus practically diminishing the volume of air set in motion, and increasing the ratio of length to width. A sliding plate (*g*, fig. 1,) of thin sheet-iron serves to narrow the embouchure at will. By varying the force of the blast from the lungs eight or ten successive notes of the harmonic series are thus secured and compared at the same time with those obtained by aid of the wire and labeled scale. The stop can then be thrust into one pipe, and several of the odd series of harmonics elicited.

The wall of the pipe next the operator is perforated with three small holes, at distances $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, from the open end. These are kept stopped with plugs, which may be removed at will. Immediately around them the wall is covered with sheet rubber (*h*, *h*), to secure an air-tight fit for the funnel (*k*) from which a tube (*l*) conveys waves to a manometric capsule. The position of nodal points in the air-column is thus shown. By fitting the tube (*l*) upon a Y-tube like that shown at (*m*), and interposing between this and another Y-tube a pair of rubber tubes, one of which is longer than the other by a half wave-length, the apparatus can be utilized for illustrating interference, with the aid of the manometric flame.

40 West Fortieth street, New York, May 3d, 1882.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *New apparatus for determining Melting Points.*—Cross and Bevan have proposed a simple method for determining melting points which is free from some of the objections of other methods. A small strip of thin sheet iron 9 by 17^{mm} has a hole cut at one end to admit the bulb of the thermometer, which it fits somewhat closely, and contains a small indentation near the other end $1{\cdot}5^{mm}$ deep and 2^{mm} in diameter. A glass float is also made, of very fine tube with a small bulb at its lower end, into which is sealed a piece of platinum wire bent at right angles at its extremity. To make an observation, a very small quantity of the substance is melted in the indentation of the plate and while still liquid the platinum wire of the float is placed in it and allowed to become fixed by cooling. The plate is then attached to the thermome-

ter and the whole is immersed in mercury. On heating this slowly, the thermometer being watched, a point is reached at which the substance melts and the float is liberated, rising to the surface of the mercury. Figures are given to show the accuracy of the new method. Purified paraffin fused at 52·5°, resorcinol at 105·0°, mercuric chloride at 258·3° and sodium nitrate at 286·8°—*J. Chem. Soc.*, xli, 111, March, 1882. G. F. B.

2. *On the Critical Temperatures of Organic Liquids.*—Pawlewski has given the results of an extended investigation of the critical temperatures of organic liquids. He finds, (1) that the critical temperatures of homologous compounds differ from their boiling points by a constant quantity; (2) that isomeric ethers have the same or very nearly the same critical temperatures; (3) that bodies in which double union of carbon occurs possess considerably higher critical temperatures than their isomers in which there is no such union, agreeing in this particular with the boiling points; (4) that the critical temperature T_m of a mixture of two liquids can be expressed by the formula $T_m = \frac{nT+(100-n)T'}{100}$, in which n and $100-n$ are the percentages of the constituents and T and T′ their critical temperatures; (5) that the above formula gives the means for determining the critical temperatures of bodies of high boiling points from their more volatile mixtures; since, if the critical temperature and the percentage composition of the mixture are known, as well as the critical temperature of the less volatile constituent, that of the more volatile one is obtained by transposing the formula $T' = \frac{100\,T_m - nT}{100-n}$; (6) that the percentage composition of mixtures of volatile liquids can be obtained from the same formula, provided the critical temperature of the mixture and of each constituent is known, since $n = 100\left(\frac{T_m - T'}{T - T'}\right)$. Owing to the facility with which water attacks glass at high temperatures, the action beginning even at 240°, the author has not been able to fix very accurately the critical temperature of this liquid.—*Ber. Berl. Chem. Ges.*, xv, 460, March, 1882. G. F. B.

3. *On a new Carbon Sulphobromide.*—Hell and Urech have observed that bromine readily reacts upon carbon disulphide. If a mixture of these substances, best in the proportion of two molecules of the former to one of the latter, be allowed to stand for some days and then the excess of CS_2 be distilled off in a water bath, a brownish-red oily residue is left, which does not solidify if protected from moisture, but which by the action of water becomes a mass of yellow crystals, which can be purified by recrystallization from ether. Alcohol also causes the crystallization. The new body is thus obtained in the form of small, bright prismatic crystals—or if slowly separated, of rhombic plates—having the composition $C_2S_3Br_6$, or carbon trisulpho-hexabromide. It fuses at 125° to a red liquid and solidifies unchanged

on cooling. At higher temperatures it decomposes evolving brown-red condensible fumes and leaving a coal. When pure it has no odor or taste. It is insoluble in water, difficultly soluble in cold ether, alcohol and glacial acetic acid, somewhat more easily in benzene, petroleum naphtha, chloroform, and entirely in CS_2 and bromine. Dilute alkalies in the cold are without action; on heating with NaOH it decomposes as follows:

$$C_2S_3Br_6 + (NaOH)_{12} = (Na_2CO_3)_2 + Na_2S_3 + (NaBr)_6 + (H_2O)_6.$$

The author gives four possible constitutional formulas for this body, $S\begin{cases} C\begin{cases} -Br \\ =S=Br_2 \end{cases} \\ C\begin{cases} \equiv S=Br_2\text{'} \\ -Br \end{cases} \end{cases}$ $S\begin{cases} C\begin{cases} =Br_2 \\ -S-Br \end{cases} \\ C\begin{cases} -S-Br\text{'} \\ =Br_2 \end{cases} \end{cases}$, $Br_2S\begin{cases} C\begin{cases} =Br_2 \\ -S \end{cases} \\ C\begin{cases} -S \\ =Br_2 \end{cases} \end{cases}$ and $Br_2\equiv C-S-S-S-C\equiv Br_2$. He gives the preference to the latter on account of the decomposition products. The oily body from which it was produced gave on analysis CS_2Br_4 or $Br_2=S=C=S=Br_2$. The crystalline body is therefore a condensation product of the oily one.—*Ber. Berl. Chem. Ges.*, xv, 273, February, 1882. G. F. B.

4. *On a new Sulphur oxychloride.*—Ogier has obtained a new oxychloride of sulphur by heating to 250° in sealed tubes a mixture of equal weights S_2Cl_2 and SO_2Cl_2. The liquid becomes dark red in color and on opening the tubes SO_2 is evolved, and a liquid remains which distills at 60°, and gives on analysis the formula S_2OCl_4. It is formed according to the equation $(S_2Cl_2)_2 + (SO_2Cl_2)_2 = (S_2OCl_4)_2 + SO_2 + S$. It is a dark red liquid of density 1·656 at 0°, and of a repulsive odor recalling that of sulphur chloride. Water decomposes it, yielding sulphur, sulphurous and sulphuric acids, hydrogen chloride and some thionic acids. Heat of 100° decomposes it into sulphurous oxide, sulphur chloride and chlorine. Its calculated density is 3·84; observed 3·98, 3·84, 3·75 by Victor Meyer's method; 3·9 by the method of Dumas. The author supposes it to be derived from the hypothetical body S_2O_3 by the substitution of Cl_4 for O_2.—*Bull. Soc. Ch.*, II, xxxvii, 293, April, 1882. G. F. B.

5. *On the Physical Properties of Carbon Oxysulphide.*—The purification of carbon oxysulphide from carbon disulphide is a difficult process. Ilosvay proposes to pass the mixture through a column of freshly calcined charcoal, which totally removes the CS_2. With the gas thus purified the author has determined some of its physical properties. Its expansion-coëfficient was measured by Regnault's method, somewhat modified, both at constant pressure and constant volume. Nine determinations at constant volume, the gas being renewed five times, and the pressure varying from 741·29 to 766·2^{mm}, gave as a mean for $1 + 100\alpha$, 1·37317. The mean under constant pressure was 1·37908. In the Cailletet apparatus the gas was easily liquefied, the pressure required at various temperatures being as follows: At 0°, liquid at 12·5 at-

mospheres; at 3·8°, 15·0; at 10·7°, 17·5; at 12·0°, 19·6; at 17°, 21·5; at 39·8°, 44; at 41·2°, 45; at 63·0°, 59; at 69°, 65; at 74·6°, 74; at 85°, 80·0. The critical point was found to be at 105°. Liquid COS is colorless, very mobile, highly refractive. Expanded suddenly it freezes in small solid flocks. It dissolves sulphur, and mixes with alcohol and ether, but not with water or glycerin. It is thus intermediate in its properties between CS_2 and CO_2.—*Bull. Soc. Ch.*, II, xxxvii, 294, April, 1882. G. F. B.

6. *On the Formation of Metallic Alloys by Pressure.*—In 1878 and 1880 Spring showed that many substances when submitted to a pressure of several thousand atmospheres formed masses looking very much as if they had been melted. Moreover he observed that when a less dense allotropic form, as prismatic sulphur, was pressed in this way, it became a more dense variety, octahedral sulphur. Yellow mercuric iodide passes into red solely by pressure. In general a chemical reaction will be effected by pressure provided the resultant is denser than the components, copper and sulphur giving under pressure, cuprous sulphide. Hence the author enunciates the general proposition that matter assumes the state or condition which corresponds to the volume it is forced to occupy. Alloys suggested themselves to him as likely to prove this law, since were the mass after pressure only a mixture, the fusing point would not have changed. A coarse powder of filings of bismuth, cadmium and tin, in the proportions required to form Wood's fusible metal, was prepared and submitted to a pressure of 7500 atmospheres. The block was reduced to filings and again pressed. It now resembled Wood's alloy completely in density, color, hardness, brittleness and fracture. Moreover it melted completely in water at 70°. A similar mixture of lead, bismuth and tin in the proportions of Rose's alloy, after two pressings, melted in boiling water. Zinc and copper filings after five or six pressings gave a mass closely resembling brass. He quotes an experiment by Romma who sought to make a fine platinum wire by drawing it down in a cylinder of silver and then dissolving the silver off with nitric acid, after Wollaston's method. But to his surprise both platinum and silver dissolved in the acid, the pressure in the die-plate having united the two into a definite alloy.—*Ber. Berl. Chem. Ges.*, xv, 595, March, 1882. G. F. B.

7. *On a Symmetrical Chlor-ethyl oxide.*—The isomers aldehyde and ethylene oxide form many analogous compounds, but though the glycol of ethylene has long been known, that of ethylidene has not been prepared. Hanriot has sought to produce the monochlorhydrin of ethylidene glycol by acting on aldehyde with hydrogen chloride, the latter being passed into the liquid, cooled to 5°, in a slow stream so long as it remains clear. The aldehyde absorbs nearly two-thirds of its weight of HCl. The liquid is then immediately distilled, in vacuo, a vessel of caustic lime being placed between the receiver and the water pump. Under a pressure of 1^{cm} of mercury a liquid passes over boiling

between 25° and 30° having the composition C_2H_5OCl. On standing it becomes turbid and breaks up according to the equation $(C_2H_5OCl)_2 = C_4H_5OCl_2 + H_2O$, into the ethylidene oxychloride of Lieben and water. The former distills at 52° under a pressure of 4^{cm} of mercury. The first of the above liquids being ethylidene monochlorhydrin $\begin{matrix} CH_3 \\ | \\ CH \end{matrix}\Big\{\begin{matrix} OH \\ Cl \end{matrix}$, the author regards the second as symmetrical mono-chlorethyl oxide $\left.\begin{matrix} CH_3CHCl \\ CH_3CHCl \end{matrix}\right\}O$, analogous to ethyl oxide $\left.\begin{matrix} CH_3CH_2 \\ CH_3CH_2 \end{matrix}\right\}O$. This constitution he has verified by causing zinc ethyl to react upon the body. The action is prompt and there results $\begin{matrix} CH_3CHCH_2CH_3 \\ O \\ CH_3CHCH_2CH_3 \end{matrix}$ secondary butyl oxide. Sodium ethylate gives the same ethylidene oxychloride in which one of the chlorine atoms is replaced by oxethyl.—*Ann. Chim. Phys.*, V, xxv, 219, February, 1882.

G. F. B.

8. *On the Constitution of Quinones.*—Japp and Streatfeild have pointed out the probability that the reaction with aldehyde and ammonia belongs to the class of condensations in the ortho series and that consequently it ought not to be capable of extension to para-quinones. Indeed they suggest this reaction as a proof of the ortho-position in quinones. Having found that both benzoquinone and *α*–naphthoquinone yield with benzaldehyde and aqueous ammonia, nothing but brown resinous products, they tried chryso-quinone and *β*–naphthoquinone. Three grams of the former was heated with an excess of benzaldehyde and aqueous ammonia to 100° for one hour in a sealed tube. On solution in hot benzene, silky needles were obtained of the composition $C_{25}H_{15}NO$, being benzenyl-amido-chrysol.—*J. Chem. Soc.*, xli, 157, April, 1882.

G. F. B.

9. *On the Preparation of Alizarin-orange.* — Simon has observed that if dinitro-oxyanthraquinone is suspended in boiling water and very little of a 20 per cent solution of sodium hydrate be added, a deep red solution of the sodium salt is at first formed and then the color passes into purple, and a dark red flocky sodium salt separates. This decomposed with HCl and the yellow residue crystallized from glacial acetic acid, gave beautiful orange-red needles of a mono-nitro-alizarin, *β*-nitro-alizarin. It fuses at 244°, and dyes orange with alumina. The reaction is: $C_{14}H_5O_2(OH)(NO_2)_2 + KOH = KNO_2 + C_{14}H_5O_2(NO_2)(OH)_2$. The constitution of the dinitro-body is thus fixed.—*Ber. Berl. Chem. Ges.*, xv, 692, March, 1882.

G. F. B.

10. *Photometric Investigation.*—In this paper E. Ketteler and C. Pulfrich continue earlier work (Wied. Ann., xii, p. 481, 1881). The absorption curves of various substances are considered as composed of several curves, and a special study is made of Glan's photometer; the instrument is then applied to a very careful

study of the absorption curves of cyanine, with a view to modifying the theoretical formulas which are used to express the absorption relations. It is found that the extinction coëfficient of a colored solution is closely proportional to the amount of the coloring matter. The study of the composite character of the absorption curves give certain values of the constants used in the theoretical formulas. A portion of the paper is devoted to a reëxamination of the question of the connection between refraction and absorption. —*Ann. der Physik und Chemie*, No. 3, 1882, pp. 337–378. J. T.

11. *Theory of Elliptical double Refraction.*—E. LOMMEL applies the theory of light, previously enunciated by him, to this subject, and finds a satisfactory agreement between theory and experiment. His earlier papers are contained in Wied. Ann., iv, p. 58, 1878; Wied. Ann., xiv, p. 523, 1881.— *Wied. Ann.*, No. 3, pp. 378–391, 1882. J. T.

12. *Difference of Potential between a Metal and Fluids of different Concentration.*—Dr. ERASMUS KITTLER continues his work upon this subject with especial reference to chloride of lithium, chloride of barium, chloride of strontium, chloride of calcium, chloride of magnesium and chloride of manganese.—*Ann. der Physik und Chemie*, No. 3, 1882, pp. 391–412. J. T.

13. *Electrical Resistance of a Vacuum.*—E. EDLUND* reviews the observations of various experimenters upon the electrical resistances of gases in different states of rarefaction, and finds that the phenomena observed can be explained on the hypothesis that a vacuum conducts electricity. With this hypothesis he finds no difficulty in explaining the connection between electrical disturbances on our earth with various phenomena going on on the sun's surface. The celestial bodies are mutually influenced not only by the law of gravitation and light and heat rays, but also by electrical energy. If a vacuum is a good conductor of electricity, an electrical charge upon one planet or star would communicate by induction a corresponding charge in other celestial bodies, and an electrical pulsation would be propagated through space. It appears to the author that the hypothesis that ordinary matter is a necessary medium for electrical action is erroneous; and the terms expressing conductibility therefore lose all physical meaning. Various material bodies oppose a greater or less resistance to the propagation of electrical disturbances. The action of these bodies is passive not active.—*Ann. der Physik und Chemie*, No. 4, 1882, pp. 514–533. J. T.

14. *Solar Heat.*—The engines of Mouchot and others which are designed to utilize solar radiation have suggested the possibility of great economy of fuel. M. A. CROVA gives a short note upon the results obtained by a commission appointed by the minister of public works. The commission carried on the experiments at Montpellier, and used a mirror having a section of $5{\cdot}22^{mq}$ normal to the solar rays, which were concentrated upon a blackened boiler placed at the focus. The boiler was surrounded by a glass

* See also p. 149.

cylinder, and the steam arising from the boiler was condensed in a serpentine condenser. The number of calories utilized by the apparatus was deduced from the weight of water distilled per hour; and hourly actinometric observations gave the number of calories that were received by the apparatus. At the same time the temperature of the air, its hygrometric state, and the heat of the sun were measured; and the thickness of the atmospheric layer traversed was calculated by the formula of Laplace. The number of calories utilized and that received were expressed in great calories (kilogramme-degré) received in one hour upon 1^{mq} of surface normal to the solar rays; their quotient gave the efficiency of the apparatus. The following table expresses the principal results obtained:

Average Value of Results obtained during 1881, *per* 1^{mq} *per* 1^{h}.

	Cal.	Maximum Cal.	
Heat received directly	616·1	945·0	(25 April.)
Heat utilized by apparatus	258·8	547·5	(15 June.)
Mean of efficiency	0·491	0·854	(14 June.)

Under the most favorable circumstances, that is to say, with an incident radiation of 1200 cal. per square meter per hour, which was never obtained, and with an efficiency of eighty per cent, 960 cal. would result. This number represents very nearly the heat produced by 240^{gr} of coal, admitting that nearly one-half of the heat that it produces in burning is utilized in converting water into steam. In reality, in the climate of France not one-half of this efficiency is obtained. The sun does not shine continuously enough to make an apparatus of the description used by the commission practicable. The possibility of its utilization in very hot and dry climates depends upon a number of circumstances, among which enter the difficulty of procuring fuel and the cost of the solar apparatus.—*Comptes Rendus*, No. 14 1882, pp. 943–945.

J. T.

15. *Aconitic Acid, from Sorghum Juices.*—H. B. Parsons (Amer. Chem. Journal, iv, No. 1), has examined the scale which deposits from clear defecated sorghum juice, after treatment with milk of lime to faint alkalinity, on boiling, and which adheres as a light buff-colored deposit tenaciously to the evaporating pans. This scale is easily soluble in hydrochloric acid without effervescence, and the solution reacts abundantly for lime and magnesia but not for glucose or sucrose. Hence it is not a lime sucrate or sulphate, as has been supposed. Analysis showed the presence of lime and magnesium oxides with water and organic matter. Eliminating accidental impurities and considering the scale an impure lime salt, it gave the composition H_2O 7·95, CaO 24·32, organic matter 67·73. The organic acid was separated from the finely pulverized scale by dilute sulphuric acid in quantity short of saturation of the calcium, and salts of zinc, lead, silver, magnesium and calcium respectively found with it and subsequently analyzed with results very closely agreeing to the assumption that the sorghum scale is a two-thirds metallic calcic aconitate

with one molecule of combined water ($CaHC_6H_3O_6 . H_2O$) aconitic acid $= C_6H_6O_6$. Arno Behr has determined the presence of aconitic acid in the melado of the West Indies, (Bericht. der deutsch. Chem. Ges., x, 351). It also exists, as is well known, in the juices of the Monkshood or Wolfsbane (*Aconitum Napellus*), and of Blue rocket (*Delphinium Consolida*) as calcium aconitate, the same salt now found in sugar cane juice and sorghum. B. S.

II. Geology and Natural History.

1. *The Climatic Changes of later Geological Times: a Discussion based on observations made in the Cordilleras of North America*; by J. D. Whitney. Part II. pp. 121 to 264, 4to. Vol. vii, No. 2, Part II, of the Memoirs of the Museum of Comparative Zoology, Cambridge. 1882. Printed for the Museum.—The first part of this memoir, covering 120 pages, was published in 1880, and is noticed in volume xx, of this Journal (p. 460). The view which Professor Whitney partly presented, and supported by facts from North America, in the preceding pages of his memoir—that secular desiccation of the globe, begun as far back as the Cretaceous era, was still in progress—is illustrated further, in this Second part, by facts from "the Asiatic Continent and other portions of the world," after which follows a discussion of the desiccation-question as to its relation to other events, and its possible causes. The facts brought forward are largely those of historical time, which he has gathered with much research from the publications of historians and travelers, but partly from his own personal observations. They are skillfully and fairly presented, making pages of reading full of interest to the general reader not less than to science; for the question whether the world is more or less slowly becoming dried up and unfit for human existence is one of wide concern. The following statements are condensed from its pages.

The region about the Mediterranean in Asia and Africa, and to a less extent in Europe, that is, from the Western Himalayas, westward—the area of the early development of the race, and once inhabited by a dense population that led the world in civilization—has lost its preëminence, and a large part of the people now rank among the semi-barbarous of the world. The causes of this degradation have been many; but one physical cause has made "life no longer possible there except under conditions which are not compatible with density of population or with intellectual vigor"—namely, "the countries in question have become very materially drier than they were during the earlier historic period."

This proposition is sustained by citations from observers as to the dimmishing water-surface of the basin of the Aral and Caspian, and the dryness of the table-land of Persia, on account of which the population has diminished and is necessarily diminishing; which dwindling of lakes and drying of streams and land Mr. W. T. Blanford, the geologist of the Anglo-Persian Boundary Com-

mission, has attributed to a gradual reduction in the rainfall of modern times, consequent on a gradual change in the climate of Central Asia. The diminution of lakes and the making the number few where once there were many in Western Thibet and Turkestan is attributed to the same general cause by Von Schlagintweit and the Geological Survey of India—"a progressive decrease of precipitation." The same report is derived from other parts of Asia. Among many other similar accounts it is said of Arabia—"it is a well established fact that the volume of flowing water is constantly diminishing;" of the region bordering on the lower Euphrates and Tigris, once the most fruitful land of antiquity, "the garden of the world," the alluvial bottoms are now covered with plants of a saline soil; of the peninsula of Sinai, "undoubted traces of rich pasturage, of watered ground and of human habitation," were found by Messrs. Tyrwhitt-Drake and Palmer "where all is now a howling waste," and "the area of some 3,000 square miles, formerly so rich in oases, which, thirty-one centuries ago, could send into the field 135,000 swordsmen, is abandoned to a few hundreds of a mongrel Egypto-Bedawi race, half peasants, half nomads;" of Egypt, a similar history; of Greece, as Professor Unger reports—"instead of the former fruitful and well-watered meadows and pastures, now only dry fields and bosky hills devoid of forests are to be found, and, in consequence of this, it is impossible that Greece should ever be again drawn within the circle of Western culture;" and Professor Fraas, recognizing the same cause, says: "On the present soil of the Nile-land never again will any philosophical system be developed, and no power in the world could cause a university to arise there which should have even the most distant resemblance to a European one." The facts of this kind given are very numerous; a few only as examples of them are here cited. The fact of gradual desiccation is further sustained by reports with regard to the Sahara region, Central Africa and South America.

In discussing causes for the desiccation in progress since the Cretaceous era, Professor Whitney sets aside the idea of any effect from the removal of forests, and of any connection with the conditions of the Glacial era, remarking that writers on that era have confined the time of excessive precipitation and its decline to the Glacial and Champlain periods, or the Glacial period only. He then refers to the increase in later geological eras of the extent of land over the globe in proportion to that of water as a real cause but a feeble one, it accounting for only a small part of the diminished precipitation. Finally, he takes up the question —"Has the solar radiation been diminishing in intensity during all or any portion of geological time," and decides that the earth's temperature has been diminishing; and for the reason that the sun has been losing in heating power. In the third part of Professor Whitney's important memoir, yet to be published, he will endeavor to show that "the ideas maintained are not in conflict with the phenomena of the so-called Glacial epoch."

2. *Third Appendix to the Fifth Edition of Dana's System of Mineralogy;* by EDWARD S. DANA. 136 pp. 8vo. New York: (John Wiley & Sons).—This Third Appendix is stated to be designed to make the System complete up to January, 1882. It follows the second Appendix after an interval of seven years, a period which has been remarkable for the unprecedentedly large amount of work done; these facts explain why the present Appendix is double the size of the preceding. It contains full descriptions of all species announced as new, some three hundred in number, and also references to all mineralogical memoirs, published during this period. From the latter many new analyses are quoted and new facts in regard to physical characters and localities. A list of mineralogical works and of mineralogical journals is given in the Introduction.

3. *The Genus Monticulipora.*—Mr. S. A. MILLER has an article in the Journal of the Cincinnati Society of Natural History, for April, 1882 (v, p. 25), showing that the subdivisions of this genus of fossil corals proposed by Professor H. A. Nicholson in his recent memoir, based on specimens from the Cincinnati group, in Ohio, have various objections, and criticising other points in the memoir.

4. *Handbook of Invertebrate Zoology for Laboratories and Seaside Work;* by W. K. BROOKS, Ph.D., Associate in Biology and Director of the Chesapeake Zoological Laboratory of the Johns Hopkins University. 392 pp. 8vo. Boston, 1882. (S. E. Cassino.)—An excellent work, well adapted for its purpose by its judicious arrangement and detailed directions for investigation, and its numerous and admirable illustrations, and attractive also in its letter-press. It is just the hand-book for a sea-side student in zoology, in fact for the learner in zoology anywhere.

5. *The Absorption of Metallic Oxides by Plants*, is the title of an interesting paper read by Professor F. C. PHILLIPS, of Western University, before the Engineers' Society of West Pennsylvania, in February last. It gives the history of what is known and thought about the effect of metallurgical works on adjacent vegetation and the influence of poisonous oxides in the soil; and then adds a summary of experiments made by Professor Phillips upon great numbers of young plants of *Coleus*, *Achyranthes*, *Ageratum*, pansies and geraniums, grown in pots for bedding, the object being to determine whether any injurious effects are produced upon plants by being grown in soil impregnated with certain metallic oxides, and whether plants in a perfectly healthy state will absorb such oxides through their roots. The conclusions reached were:

(1.) That healthy plants, grown under favorable conditions, may absorb through their roots small quantities of lead, zinc, copper and arsenic.

(2.) That lead and zinc may enter the tissues in this way without causing any disturbance in the growth, nutrition, and functions of the plant.

(3.) That the compounds of copper and arsenic exert a distinctly poisonous influence, tending, when present in larger quantity, to check the formation of roots, and either killing the plant or so far reducing its vitality as to interfere with nutrition and growth.

In the case of the heavy metals, copper, zinc, arsenic and lead, it seems to be probable that their oxides may under certain circumstances become deposited in the tissues of the plant.

6. *Monographie des Composées*, par H. Baillon. Paris, 1882. pp. 316.— This is the 8th volume of Baillon's *Histoire des Plantes.* One-third of the volume is occupied with an exposition of the floral structure of composite plants, illustrated by the excellent wood cuts which so well set off this and other French botanical books, and with a sketch of the medicinal uses of these plants. In the remaining 212 pages the admitted genera are characterized in large and leaded type, with rather copious bibliographical references in foot-notes. Now Mr. Bentham filled 370 pages of the *Genera Plantarum*—pages of just the same size, but of fine type—with his characters of the tribes and genera of this order. In his laborious and conscientious review of the family, by a botanist who is not at all prone to the multiplication of genera, and who is thought in some cases to have gone too far in reduction, the genera admitted (including a few addenda) amount to 780. The difference in the bulk of the two works is accounted for by the reduction of the genera by Baillon to 403. Baillon's specialty is generic consolidation. Yet withal he keeps up several genera which we find it impossible to maintain; and there are others which should have been suppressed upon his principles, though not upon ours. Deducting these, the genera according to Baillon would be only half as many as those of Bentham and Hooker. Baillon is an able botanist and is entitled to have his own views. If his plan is not adopted, as being neither philosophical nor practically convenient, it is harmless as compared with the opposite extreme; and nothing can be easier than to double up the genera upon a preconceived line after all the materials had been well elaborated beforehand. A. G.

7. *Guide to the Flora of Washington and vicinity*, by Lester F. Ward, A.M. pp. 264, 8vo.—This capital piece of work is published by the U. S. National Museum as Bulletin No. 22, and "one of a series of papers intended to illustrate the collections of natural history and ethnology belonging to the United States and constituting the National Museum, of which the Smithsonian Institution was placed in charge by Act of Congress of August 10, 1846."

The introductory portion treats first of the range of this "flora Columbiana," which is said to be limited on the north by the Great Falls of the Potomac and on the south by the Mt. Vernon estate; it compares the present known flora of the district with that of 1830, as exhibited in the *Floræ Columbianæ Prodromus* by the botanical club of that day; describes in some detail the

localities of special interest to the botanist; indicates the flowering time of the plants and its variation in different years; tabulates and discusses the statistics of the flora; specifies the sixteen largest orders* (these furnishing 55 per cent of the genera and 62 per cent of the species), also the 15 larger genera (beginning with *Carex* and ending with *Asclepias*); mentions the number of introduced species (193, of which 15 are natives of the United States, several indeed hard by), also of the trees (85); institutes comparisons with other floras; and particularly notes the abundant species, those which therefore impress their character upon the landscape. This is a particularly good point; and we are pleased to find that the prominent forest trees, smaller trees, shrubs, woody climbers, and the more conspicuous herbaceous species are in turn enumerated. There are some critical and more explanatory remarks about classification, generally to the purpose. (But it is a mistake to say that, in the New Genera Plantarum, "*Valerianella* has been made coëxtensive with *Fedia*. European authors almost without exception keep up the two genera, it seems to us without good reason. *Steironema* was not adopted in that work only because the authors did not know the peculiar æstivation of the corolla; it was adopted here upon the discovery of this character.) There are good remarks upon common names, i. e. vernacular names; and it is well said "that the best common name for a plant is always its systematic name, and this should be made a substitute for other popular names, whenever and wherever it can be done." We have come to agree with DeCandolle, in urging that while vernacular names are freely to be used in their place, they ought never to be made. A deliberately manufactured vernacular name is a contradiction and a counterfeit. Exceptions there may be, where a generic name may be aptly translated, but these are few.

The flora itself makes up only about 80 pages of this volume. It is a catalogue, without characters or synonymy,—these being at hand in the manuals and proper floras,—but with localities, time of flowering, and many particular observations. It should essentially facilitate and further the study of botany in and around the District of Columbia.

Following the flora is a "check list," with ample room for notes, which occupies 60 pages. The uses of this are explained in the appendix. While the work itself is calculated for the meridian of Washington, the appendix will be very useful wherever there is any botanizing, or any disposition to botanize. It consists of "suggestions to beginners" respecting the identification of plants, collection and preservation of specimens, the making and care of a herbarium, the management of duplicates, of exchanges, and ends with general remarks on herbarium work; all sensible, clear and instructive. Great is the need of such instruction, especially to young United States officers and others who make botanical

* The first eight are *Compositæ*, 53 gen., 149 sp.; *Gramineæ*, 43, 110; *Cyperaceæ*, 10, 108; *Leguminosæ*, 24, 57; *Rosaceæ*, 15, 46; *Labiatæ*, 23, 43.

collections in distant expeditions. The knowledge and the tact they may here acquire should make all the difference between a neat and scientifically valuable collection and one which is repulsive and worthless.

If we rightly understand it, Mr. Ward's plant-poison is not strong enough. We recommend that the alcohol should be saturated with corrosive sublimate, and then, if need be on account of efflorescence, that just a little alcohol be added. And the alcohol should be of the strongest. This appendix covers about the same ground as does Professor Bailey's Botanist's Hand-book, noticed in the preceding number of this Journal. Both are excellent, are needed, and we hope will be widely disseminated. In view of this, it may be expected that the appendix will be separately issued and be distributed by the Smithsonian Institution. A. G.

8. *Les Meilleurs Blés, Description et Culture des principales Variétés des Froments d'Hiver et de Printemps*, par VILMORIN-ANDRIEUX.—This is a handsome imperial 4to, of 175 pages of letter-press and 66 plates, each one admirably representing, in the natural size and colors, two heads of each sort of wheat and some separate grains; not only all the best varieties of *Triticum sativum*, but also of the cultivated spelts and other wheat species, *T. turgidum*, *durum*, *Polonicum*, *Spelta*, *Amyleum*, and *monococcum*. Besides the details for each variety, in a page accompanying the figure, and some general considerations, there is an interesting chapter on the classification of the seven types or species and the many varieties of the common wheat. As this work is a practical one, only the better sorts (according to the title) are here described and illustrated. We may add that this volume comes from the collections and investigations of three generations, son and grandson having continued the collection and the studies commenced by the senior Vilmorin in the year 1820. Louis Vilmorin,—a capital investigator of all such questions,—published his Methodical Catalogue of Wheats in 1850, and died in 1860, since which the work has been prosecuted in the same spirit by the present editor, Henry Vilmorin. A. G.

9. *The Office of Resinous Matters in Plants;* by HUGO DE VRIES. A paper in the *Archives Néerlandaises*, vol. xvii, 1882.—The extract fills 24 pages, 8vo. It has been difficult to make even a plausible conjecture of the uses of the "proper juices" of plants. In their production a large amount of nutritive material is consumed; and for the most part they are stored up irretrievably in the plant, not being reconverted into nutritive material. This gave some color to the old idea that they are excrementitious. But, besides that under normal conditions they are not excreted, why should a pine-tree convert such an amount of its assimilated ternary matters into turpentine, which is merely to be excreted? Or, if it be a bye-product, what useful production or beneficial end attends the production? If excrementitious, the tree should be benefitted by drawing it off. But, as De Vries remarks, and as the owners of the trees very well know, the process is injurious, and if followed up is destructive. It goes almost without saying,

now-a-days, that the turpentine is of real good to the tree, else turpentine-bearing trees would not exist. De Vries has made out a real use, which he thinks is the true function of the resiniferous matters in *Coniferæ*, and in other resin-producing plants. Resinous juice is stored in the tree as *a balm for wounds*. It is stored up under tension, so that it is immediately poured out over an abraded or wounded surface; for these wounds it makes the best of dressing, promptly oxidating as it does into a resinous coating, which excludes the air and wet, and other injurious influences, especially the germs or spores which instigate decay; and so the process of healing, where there is true healing or reparation, or of healthy separation of the dead from the living tissues, is favored in the highest degree. The saturation of the woody layers with resin, in the vicinity of wounds and fractures (as is seen in the light-wood of our hard pines), is referred to as effectively arresting the decay which parasitic fungi set up, this "fat" wood being impervious to mycelium.

Latex or milky juice is a more complex product, of which certain portions have been shown to be nutritive; but as to the caoutchouc and the waxy matters they contain, De Vries insists that they subserve a similar office, are, in fact, a remedy,—a protection against decay, a natural provision for the dressing of wounds, under which healing may most favorably proceed. A. G.

10. *A Popular Californian Flora;* by Volney Rattan.—This is the "Third Edition, Revised and Enlarged," of a little book which we commended at its first appearance, and which, now that the Botany of California is published, has been somewhat extended. "Introductory Lessons in Structural Botany," with copious woodcuts, are prefixed. So that, all things considered, beginners in botany on the Pacific coast are fairly provided for. A. G.

III. Miscellaneous Scientific Intelligence.

1. *Astronomical and Meteorological Observations made during the year* 1877 *at the U. S. N. Observatory ;* Rear Admiral John Rodgers, Superintendent. Washington, 1881.—This volume contains the results of the regular observations, and also six valuable appendices. (1) Investigation of the Objective and Micrometer of the 26-inch Equatorial, by E. S. Holden; (2) The Multiple Star Σ 748, or the trapezium in Orion, by E. S. Holden; (3) The Solar Parallax from meridian observations of Mars in 1877, by J. R. Eastman; (4) Longitude of the Cincinnati Observatory (viz: $29^m\ 29^s{\cdot}33$ west of Washington), by J. R. Eastman; (5) Longitude of Morrison Observatory, Glasgow, Mo., by J. R. Eastman and H. S. Pritchett (viz: $1^h\ 3^m\ 5^s{\cdot}926$ west of Washington); (6) Observations of Double Stars, by Asaph Hall. Several of these appendices have been noticed in previous numbers of this Journal.

2. *American Association.*—The next meeting—the thirty-first—of the American Association for the Advancement of Science, will be held at Montreal, Canada, commencing August

23. The President of the meeting is Principal J. W. Dawson, of McGill University, Montreal. As now arranged there are nine sections, the Vice-Presidents of which are as follows:—A. Mathematics and Astronomy, WM. HARKNESS; B. Physics, T. C. MENDENHALL; C. Chemistry, H. C. BOLTON; D. Mechanical Science, W. P. TROWBRIDGE; E. Geology and Geography, E. T. COX; F. Biology, W. H. DALL; G. Histology and Microscopy, A. H. TUTTLE; H. Anthropology, DANIEL WILSON; I. Economic Science, and Statistics, E. B. ELLIOTT. A large meeting is expected. The local arrangements are being perfected by a local committee, of which Dr. T. Sterry Hunt is chairman. Of foreign scientists who have been specially invited, the following have signified their intention of being present: SZABÓ of Buda-Pest, RÉNARD of Brussels, STEPHANESCO of Bucharest, W. B. CARPENTER of London, SAMUEL HAUGHTON and FITZGERALD of Dublin, and SOLLAS of Bristol.

3. *Treatise on Astronomy, Spherical and Physical;* by W. A. NORTON. 5th edition revised and enlarged. New York. (Wiley and Sons.)—In this new edition of his well known and much valued work the author has, besides embodying the recent researches and discoveries, added in the appendices new investigations and theoretical discussions in Astronomical Physics.

Abstract of a Report upon the Geology and Mining Industry of Leadville, Colorado, by S. F. EMMONS, Geologist-in-charge Rocky Mountain Division. U. S. Geol. Survey. pp. 203–290, with two colored plates, from the Annual Report of the Director of the U. S. Geol. Survey, transmitted Dec. 1. 1881. Washington, 1882.

Report upon Experiments and Investigations to develop a system of Submarine Mines for defending the Harbors of the United States. Submitted to the Board of Engineers, by Lieut. Col. HENRY L. ABBOT, Corps of Engineers, Brevet Brigadier General, U. S. A., member of the Board. 444 pp. 4to. Washington. 1881. Professional papers of the Corps of Engineers, U. S. A., No. 23.

Insects Injurious to Forest and Shade Trees, by A. S. PACKARD, Jr., M.D. Bulletin No. 7 of the U. S. Entomological Commission, Dept. of the Interior. 276 pp. 8vo. Washington, 1881.

Report on the Meteorology of Tokio for the year 1880, by T. C. MENDENHALL, Ph.D., Professor Experimental Physics in Tokio, Daigaku. Memoirs of the Science Dept. of the Univ. of Tokio. The work contains a thorough discussion of the subject, with numerous tables, charts and diagrams.

Bulletin of the U. S. National Museum, No. 11. Bibliography of the Fishes of the U. S. Pacific coast to the end of 1879, by T. GILL. Washington, 1882.

Results of Meteorological Observations at Providence, R. I., for 45 years, from 1831 to 1876, by ALEXIS CASWELL. Smithsonian Contributions, No. 443. 34 pp. 4to. Washington, D. C., 1882.

Bulletin of the Natural History Society of New Brunswick, St. John, N. B. No. 1. 72 pp. 8vo. 1882.

Descriptions of New Species of Fossils from Ohio, with remarks on the geological formations in which they occur, by R. P. WHITFIELD. March, 1882. Vol. ii. No. 8 of the Annals N. Y. Acad. Sci.

OBITUARY.

SIR CHARLES WYVILLE THOMSON.—Sir Charles Wyville Thomson was born March 5th, 1830, at Bonsyde, Linlithgow, Scotland, where he died March 15, 1882. His father, a surgeon in the service of the East India Company, intended to make him a physician. But the medical profession had no charm for him except

as it concerned the study of nature, and he gave up the thought of practice and accepted a lectureship on botany, first at King's College, Aberdeen, and afterward at Marischal College. During the two years of his lectureship he devoted much of his time to the study of the Invertebrates, and at the age of twenty-three he was appointed Professor of Natural History at Queen's College, Cork. Here he remained but a year, being called in 1854 to the Professorship of Mineralogy and Geology at Queen's College, Belfast, a position which he occupied till he became the successor of Professor Allman as Regius Professor of Natural History in the University of Edinburgh. This post he resigned a few months before his death on account of ill-health.

The versatility of Professor Thomson's attainments is shown by the variety of learned posts, all of which he filled with marked distinction. While at Belfast he wrote the greater number of those zoological memoirs which gave him an eminent rank among naturalists. Thoroughly devoted to the interests of Belfast, he brought together collections for the college there which were of value and importance. In the meantime Thomson's interest was early and strongly aroused by the investigations of the Norwegian and American naturalists into the fauna inhabiting the depths of the sea. Satisfied that so ardent and able a naturalist could not fail to turn any means placed in his hands to the best account, the government was induced to give him in successive years the "Lightning" and the "Porcupine," and finally the "Challenger" and the "Knight Errant." The first and second of these explorations into that submarine world which is the land of promise of the naturalist, were directed by Dr. Wm. B. Carpenter, Mr. Jeffreys and Professor Thomson, and the results were embodied by Thomson in a most attractive volume entitled, "The Depths of the Sea," by far the most interesting account which has ever appeared of the new zoological problems suggested by similar expeditions. Stimulated by the success of these two voyages of discovery, the Royal Society of London appointed a committee to urge upon the government the wisdom of fitting out another expedition on a gigantic scale. To this the government acceded, and in 1873 the "Challenger" started on her memorable voyage. The scientific direction of the expedition was intrusted to Thomson and for three years he and his colleagues were at work searching the depths of the Atlantic, the Pacific, and extending their researches far toward the Antarctic pole. The cruise was in every way successful, broken by only one untoward event, the death of Dr. R. von Willemoes Suhm. During this famous expedition the "Challenger" sailed over 70,000 miles of sea, pausing at 362 stations, at each of which, systematic observations were made by the naval officers and the civilian staff of investigators. Not only were most extensive collections made illustrating the novel and wonderful fauna characteristic of the ocean depths, but physical observations of the greatest importance were taken, and materials were brought

together for the first hydrographic sketch map of the great oceanic basins, as well as records and measurements of temperatures and currents wherever such were feasible.

These immense collections were sent home from time to time, and on the return of the expedition the working up of the whole mass of material was entrusted to its scientific director, Sir Charles Wyville Thomson. He selected as his assistants the best known specialists in the different branches of the animal kingdom, and three volumes of the zoology have already appeared. Unhappily Thomson's own part of the work is but little advanced, and the crinoids and sponges which he hoped to work up himself must now pass into other hands. Only two volumes of his general account of the voyage of the "Challenger" have been published, under the title of "The Atlantic." The material for the other intended volumes on the Pacific and the Southern ocean exist only in the form of notes, and in the sketch of the results of the "Challenger" expedition, given by Thomson in his address as President of the Geographical Section of the British Association at its Dublin meeting.

The death of such a man at a comparatively early age, before he had time to gather in the harvest he had so fairly won, is not only sad in itself but is a great loss to science. His extensive and exact knowledge in many fields of biology would have enabled him to put together the varied results of his expedition as no one else can do it.

Thomson was a general favorite, beloved not only by his colleagues but by his students who flocked to his lectures. Natural History was perhaps never more popular than while he held the professorship, which had been occupied in turn by Jamieson, Forbes and Allman. His relations with his foreign associates were always frank and kindly, and those who had the good fortune to meet him parted from him not only as from an old friend, but also with sincere admiration for his character and extensive attainments. A. AG.

General JOHN G. BARNARD, of the Department of Engineers, U. S. Army, died on the 14th of May. General Barnard was an able mathematician, and the author of papers on Projectiles, the Gyroscope, the Tides and other subjects.

CHARLES M. WHEATLEY, of Phenixville, Pennsylvania, Mining Engineer, died on the 6th of May. Mr. Wheatley's discoveries of a Saurian bone-bed near Phenixville in the Mesozoic shales of the region, and of a Quaternary Cave in Eastern Pennsylvania containing bones of the Mastodon, Megalonyx and other extinct species, were of the highest interest to American geology.

WILLIAM S. VAUX died at Philadelphia on the 5th of May. Mr. Vaux used his wealth largely for scientific purposes. He gathered one of the finest collections of minerals in the country, and besides a large archæological collection. Among his bequests, there is one of $10,000 to the Academy of Natural Sciences, and another, of his Collection of Etruscan Pottery, to the Pennsylvania Museum and School of Industrial Art.

INDEX TO VOLUME XXIII.*

A

Academy, National, list of papers, 79.
Acid, aconitic, from Sorghum, 488.
carbonic, in sea-water, 53.
sulphuric, freezing point of, 236.
Aerolites, see *Meteorites*.
Agassiz, A., Cretaceous and recent Echinid faunæ, 40.
Challenger Echinoidea, 75.
obituary of C. Wyville Thomson, 496.
Air-thermometer for chemical purposes, 143.
Alizarin-orange, preparation of, 486.
Allantoin, in vegetables, 147.
Alloys, formation of, by pressure, 485.
Ammonium tribromide, 145.
Animals, see ZOOLOGY.
Association, American, 495.
Asteroids, see *Planets*.
Astronomische Nachrichten, 160.

B

Bailey, W. W., Botanical Collector's Handbook, 246.
Baillon, H., Monographie des Composées, 492.
Barker, G. F., chemical abstracts, 143, 234, 409, 482.
Becquerel, H., magnetic properties of nickeliferous iron, 229.
Beebe's Four-Place Tables, 162.
Bell, A. G., apparatus for determining the position of a projectile of metal in the body, 46.
Bentham, G., Notes on Gramineæ, 244.
Bohnensieg, Annual of Botanical Literature, 70.
Boss, comet vii, 1881 (Swift), 77.
Boston city water, 250.
BOTANY—
Algæ in animals, 328, 329.
Asia, plants of, 245.
Compass-plants, 159.
Coniferæ, female flowers of, 418.
Coriaria, 159.
BOTANY—
Flora Brasiliensis, 244.
Hypericum, 245.
Ilex, 159.
Leaves, motions of in the light, 245.
Lepturus paniculatus, 71.
Lichens, North American, 326.
Metallic oxides in plants, 491.
Monochasma, 159.
Nomenclature, 157.
Philozoon, 329.
Plants, respiration of, *Wilson*, 423.
Resins, office of, in plants, 494.
Schænonardus Texanus, 71.
Spongilla in Boston city water, 250.
Timber-line, *Gannett*, 275.
"Yellow cells" of radiolarians and cœlenterates, 328.
Zoochlorella, 329.
See further under GEOLOGY.
Brooks, W. K., Invertebrate Zoology, 491.
Bullet, apparatus for determining the position of in the body, *Bell*, 46.
Burnham, S. W., transit of Mercury, 1881, 48.

C

Cæsium, production and properties of, 411.
Carbon oxysulphide, physical properties of, 484.
Carbon sulphobromide, new, 483.
Chemical change, illustration of, 237.
Chemistry, celestial, *Hunt*, 123.
Chinoline, reactions of, 146.
Chlor-ethyl oxide, symmetrical, 485.
Cinchona bark, new alkaloid from, 412.
Cincinnati Society of Natural History, Journal of, 65.
Claassen, E., potassium chloride in absinth, 323.
analysis of siderite, 325.
Clarke, J. M., new Devonian phyllopods, 476.
Clerk-Maxwell, J., Treatise on Electricity, 149.

* This Index contains the general heads BOTANY, GEOLOGY, MINERALOGY, OBITUARY, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.

Coal, see GEOLOGY.
Color correction of double objectives, *Hastings*, 167.
Comet vii, 1881, elements of, 77.
Comets, notation of, 160.
Cook, G. H., New Jersey Geological Report, 325.
Cooke, J. M., Gundlachia in western New York, 248.
Cope, E. D., Eocene vertebrates of New Mexico and Wyoming, 324.
Copper implements, how formed, 162.
Crosby, W. O., geology of Frenchman's Bay, Maine, 64
Cross, W., minerals in basalt of Table Mountain, 452.
Cymene, preparation of, 412.

D

Dana, E. S., monetite crystals, 405.
Third Appendix to Dana's Mineralogy, 491.
Dana, J. D., flood of Connecticut valley glacier, 87, 179, 360.
Darton, N. H., new locality for Hayesine, 458.
Darwin, F., movements of leaves in the light, 245.
Darwin, G. H., lunar disturbance of gravity, 49.
Daubrée, joints in strata, 63.
Derby, O. A., geology of the diamond, 97.
gold-bearing rocks of Minas Geraes, Brazil, 178.
Brazilian specimens of martite, 373.
Diffusion of solids into solids, 409.
Dinosauria, see GEOLOGY.
Dissocioscope, 235.
Draper, H., photographs of spectrum of nebula of Orion, 339.
Drops floating on water, 50.
Duncan, P. M., Arctic Echinodermata, 247.
Dutton, C. E., Fisher's Physics of the Earth's Crust, 283.
Dynamo-electric machine, 147.

E

Earth, density of, 51.
physics of crust of, 283.
Earthquake in Ischia, 337.
Earthquakes, American, *Rockwood*, 257.
of Switzerland, 337.
Earths, metals of the rarer, 412.
Eastman, J. R., solar parallax, 160.
Edison's electrical meters, 52.
Eichler, A. W., Jahrbuch des königlichen botanischen Gartens, 70.
female flowers of Coniferæ, 418.
Electrical meters, Edison's, 52.
rays, reflection of, 413.
resistance of gases, 321, 487.
of a vacuum, 149, 487.
units, 241.
Electricity, inertia of, 240.
storage of, 414, 415.
Electrification by evaporation, *Freeman*, 428.
Electrodes, disintegration of, 240.
Electrolytes, dielectric polarization in, 321.
Electro-magnetism, theory of, 240.
Elliott, H. W., Seal-islands of Alaska, 334.
Emerson, B. K., dyke of Elæolite-syenite in New Jersey, 302.
diabase intersecting zinc ore, 376.
Englemann, G., female flowers of Coniferæ, 418.
Engler, Botanische Jahrbücher, 71.
Ether, nature of, *Hunt*, 123.

F

Farlow, W. G., botanical notices, 159, 326, 329.
Fewkes, J. W., a Cercaria with caudal setæ, 134.
Fisher, O., the Earth's Crust, 283.
Flames, new arrangement for sensitive, 51.
Fossil, see GEOLOGY.
Foye, J. C., Tables for Determination of Minerals, 418.
Freeman, S. H., electrification by evaporation, 428.
Furman, J. H., copper-bearing region in northern Texas, 65.
Fusion, see *Melting points*.

G

Gannett, H., the timber-line, 275.
Gas-densities, determination of, 409.
Gases, electrical resistance of, 321, 487.
viscosity of rarefied, 239.
Geikie, A., Director-general of geological survey of Great Britain, 338.
Geological Congress, Bologna, 150.
GEOLOGICAL REPORTS AND SURVEYS—
Minnesota, 62, 64.
New Jersey, 325.
United States, 382, 452.
Territories, 153.
GEOLOGY—
Amygdaloid of Brighton, Mass., 65.
Anthracite of Colorado, 64.
Basalt of Table Mountain, 452.
Brick-clays making cream-colored bricks in Minnesota, 64.
Cincinnati rocks, fossils of, 65.

GEOLOGY—
Climatic changes of later times, *Whitney*, 489.
Coal, coking, of Colorado, 64.
Coal-field near Cañon City. Cal., 152.
Connecticut river glacial flood, *Dana*, 87, 179, 360.
Copper-bearing region in Texas, 65.
Diabase intersecting zinc ore, *Emerson*, 376.
Diamond, geology of, *Derby*, 97.
Dinosauria, classification of, *Marsh*, 81.
Echini, Cretaceous and recent, *Agassiz*, 40.
Echinognathus, *Walcott*, 213.
Eocene of Wyoming and New Mexico, 324.
Eozoon, controversy on, 418.
Eurypterus, new, *Walcott*, 151, 213.
from near Buffalo, 418.
Evaporation and eccentricity as cofactors in glacial periods, 61.
Foyaite dyke, New Jersey, *Emerson*, 302.
Frenchman's Bay, Maine, 64.
Glacial era climate, *Woeikof*, 417.
erosion in Maine, 242.
flood, 418.
of Connecticut Valley, *Dana*, 87, 179, 360.
periods, evaporation and eccentricity in, 61.
phenomena in Maine, 242.
in Minnesota, 62.
on the Delaware, 242.
scratches in the Catskills, 338.
Glaciers, movement of, 59.
periodical variations of, 56.
of Greenland, 363.
Gold-bearing rocks, Brazil, *Derby*, 178.
Jointed structure in clay and marl, *Le Conte*, 233.
Joints, in strata near Paris, 63.
post-Glacial, *Gilbert*, 25.
Jura-Trias of S.W. Colorado, 243.
Lakes of Minnesota, 62.
Mollusks, descent of, *White*, 382.
Monticulipora, 491.
Petroleum of British America, 154.
Phyllopods, new Devonian, *Clarke*, 476.
Pœcilopod in the Utica slate, 151.
Pterodactyles, wings of, *Marsh*, 251.
Pterygotus from near Buffalo, 418.
Soil-cap motion, 59.
Syenite, Quincy, 418.
Tides in early time, 323.
Trilobites, Primordial in Sardinia, 65.
Vertebrates, Eocene, *Cope*, 324.
Geysers, apparatus illustrating action of, 320.
Gibbs, J. W., double refraction and dispersion of colors, 262.
double refraction and circular polarization, 460.
Gilbert, G. K., post-Glacial joints, 25.
Glacier, etc., see GEOLOGY.
Gould, B. A., algebraic expression of diurnal variation of temperature, 99.
Gravity, lunar disturbance of, 49.
Gray, A., botanical notices, 69, 159, 244, 326, 492.
nomenclature, 157.
compass-plant, 160.
botanical necrology, 330.
Greenland, Flora of, not., 247.
glaciers of, 363.
Groth, P., Tabellarische Uebersicht der Mineralien, 157.
Guides for Science Teaching, 336.

H

Hague, A. D., Mining Industries, 162.
Hailstorms, 249.
Hall, J., Bryozoans of the Upper Helderberg, 153.
Halogens, vapor-density of, 143.
Hastings, C. S., color correction of double objectives, 167.
Hazen, W. B., Signal Service Report, 78
Heat, Fourier-Poisson theory of conduction of, 322.
Heilprin, A., Tertiary of Eastern and Southern United States, 153.
Hilgard, J. E., appointed superintendent of Coast Survey, 162.
Hill, E., evaporation and eccentricity in glacial periods, 61.
Hillebrand, W. F., minerals in basalt of Table Mountain, 452.
Hills, R. C., Jura-Trias of southwestern Colorado, 243.
dioptase from Arizona, 325.
Holden, E. S., transit of Mercury, 1881, 48.
rings of Saturn, 387.
Holman, S. W., method for calibrating thermometers, 278.
Hooker, J. D., Icones Plantarum, 71.
Huggins, W., photograph of spectrum of nebula of Orion, 335.
Hungerford, E., snow and ice under pressure, 434.
Hunt, T. S., celestial chemistry, 123.
Hydrogen phosphide, spontaneously inflammable, 144.

I

Ice under pressure, *Hungerford*, 434.
Iles, M. W., smaltite in Colorado, 380.
vanadium in Leadville ores, 381.

Illinois Museum of Natural History, Bulletin of, 417.
Iron, determination of phosphorus in, *Smith*, 316.
magnetic properties of a nickeliferous, 229.

J

Judd, J. W., Volcanoes, 65.

K

Kayser, H., velocity of sound in wood, 415.
Klangfarbe, 147.
Kokscharof, N. v., Russian Mineralogy, 68.

L

Lalande prize, 250.
Lapparent, Traité de Géologie, 154.
Leaves, see BOTANY.
Le Conte, J., sound-shadows in water, 27.
jointed structure in clay and marl, 233.
Lichtenberg's figures, 240.
Light, absorption of, 50, 486.
electro-magnetic theory of, *Gibbs*, 262, 460.
interference phenomena of, *Michelson*, 395.
rotation of plane of polarization of, 148.
spectroscopic observations with monochromatic, 322.
Loomis, E., contributions to meteorology, 1.

M

Madan, H. G., Tables of Qualitative Analysis, 150.
Magnetism as affected by hardening, 414.
Magnetization, maximum of, 413.
Man, Paleolithic in Delaware valley, 152.
Marsh, O. C., classification of the Dinosauria, 81.
wings of Pterodactyles, 251.
Martius, E. v., Conchologische Mittheilungen, 422.
Maximowicz, C. J., Coriaria, etc., 159.
Diagnoses Plantarum novarum Asiaticarum, 245.
McGee. W. J., evaporation and eccentricity in glacial periods, 61.
Melting points, apparatus for determining, 482.
Mendenhall, Meteorology of Tokio, 496.
Mercury, transit of, 1881, 48.
Meteorites, supposed organisms in, 156.
Meteorology, contributions to, *Loomis*, 1; *Woeikof*, 341; *Mendenhall, Caswell*, 496.
Meyer, V., vapor-density of the halogens, 143.
Michelson, interference phenomena, 395.
Millimeter screw, *Wead*, 176.
MINERALS—
Analcite, 457.
Bergamaskite, 155.
Chabazite, 454.
Chrysolite, artificial, 155.
Diamond, 97.
Dioptase from Arizona, 325.
Dopplerite, 154.
Enstatite, 155.
Hayesine. 458.
Hematite, polyhædral cavities in, 67.
Hiddenite, 68.
Iron, a nickeliferous, 229.
Litidionite, 155,
Martite, Brazilian, 373.
Melanotekite, 155.
Monetite, 400, 405.
Monite, 400.
Nocerine, 155.
Orthoclase, 67.
Phytocollite, 155.
Pyroclasite, 400.
Quartz crystals, in sandstones, 257.
Siderite, analysis of, 325.
Smaltite in Colorado, 380.
Thomsonite, 455.
Vanadium, 381.
Museum, American, Bulletin of, 153.
of Comparative Zoology, Bulletin, 422.

N

Naumann, C. F., Mineralogie, not., 68.
Nebula of Orion, photograph of spectrum of, *Huggins*, 335; *Draper*, 339.
Newberry, J. S., coking coal and anthracite of Colorado, 64.
Newton, H. A., notation of comets, 160.
astronomical notices, 160.
minor planets, 249.
notice of Peirce's Algebra, 336.
Nitrogen oxides, action of on glass, 55.
Nomenclature, natural history, 157.
Nordenskiöld, A. E., Voyage of the Vega, 336.
Norton, W. A., Treatise on Astronomy, 496.

O

OBITUARY—
Andersson, Nils J., 333.
Austin, Coe F., 332.
Barnard, Gen. John G., 498.
Darwin, Charles Robert, 422.

OBITUARY—
Decaisne, Joseph, 331.
Desor, E., 422.
Draper, John W., 163.
Godron, Dominique Alexandre, 333.
Hampe, Ernst, 333.
James, Thomas P., 330.
Lindsay, W. Lauder, 333.
Mallett, Robert, 80.
Mead, S. B., 333.
Morgan, Lewis H., 166.
Munro, Gen. Wm., 333.
Rabenhorst, Gottlieb Ludwig, 333.
Schimper, Wm. Philip, 333.
Schleiden, Matthias Jacob, 333.
Schwann, Theodore, 333.
Thomson, C. Wyville, 338, 496.
Vaux, William S., 498.
Wheatley, Charles M., 498.
Wood, Alphonso, 333.
Objectives, color correction of double, *Hastings*, 167.
Observatory, Harvard College, Report of, 161.
Morrison, longitude of, 77.
National, publications of, 160, 495.
Optics, physiological, *Stevens*, 290, 346.
Organic liquids, physical properties of, 234.
critical temperatures of, 483.
Owen, R., Cephalopoda, 72.
Oxides, effect of, in the decomposition of potassium chlorate, 236.
Oxygen, production of active, 410.

P

Packard, A. S., Jr., Cambarus primævus, 153.
Chatauqua Scientific Diagrams, 418.
Peirce, B., Linear Associative Algebra, 336.
Peptones, theory of, 146.
Persulphuric oxide, so-called, 410.
Petroleum hydrocarbons, splitting of, 237.
of the Caucasus, 145.
Phillips, F. C., absorption of metallic oxides by plants, 491.
Phosphorescence, 322.
Phosphorus oxide, 144.
Pickering, E. C., Observatory Report, 161.
Planets, list of minor, 249, 334.
see also, *Mercury*, etc.
Potassium permanganate, 336.
chloride in Absinth, 323.
Potential, difference of, between a metal and fluids of different concentration, 487.
Poulsen, V. A., Botanische Mikrochemie, 328.
Powell, J. W., Report of Bureau of Ethnology, 422.
Protoplasm, nature of living, 238.
Pterodactyles, see GEOLOGY.
Putnam, F. W., palæolithic implements of the valley of the Delaware, 152.

Q

Quinones, constitution of, 486.

R

Rain-fall, annual, *Loomis*, 1, *Woeikof*, 341.
Rattan, V., Popular Californian Flora, 495.
Refraction, double, *Gibbs*, 262, 460.
elliptical double, 487.
Regelation, *Hungerford*, 434.
Remsen, I., Boston city water, 250.
Reports of Engineers, index of, 336.
Richards, E. H., Chemistry of Cooking and Cleaning, not., 416.
Rockwood, C. G., American earthquakes, 257.
notice of Judd's Volcanoes, 65.
notes on earthquakes, 337.
Rosin oil, metaisocymene in, 238.

S

Saturn, rings of, *Holden*, 387.
Schœberle, J. M., flexure of a telescope tube, 374.
Schott, C. A., rain and snow tables, 250.
Screw, millimeter, *Wead*, 176.
Sea-water, carbonic acid in, 53.
Seismological Commission, Swiss, 337.
Shepard, C. U., monetite, monite and pyroclasite, 400.
Siemens, W., dynamo-electric machine, 147.
Signal Service Report, 78.
Silliman, B., obituary of Draper, 163.
aconitic acid from Sorghum juices, 488.
Smith, J. L., magnetic properties of nickeliferous iron, 232.
determination of phosphorus in iron, 316.
Snow, effect of pressure on, *Hungerford*, 434.
Solar, see *Sun*.
Sonometer, organ-pipe, *Stevens*, 479.
Sophorin, 413.
Sound, velocity of in wood, 415.
Sound-shadows in water, *Le Conte*, 27.
Spectroscopic observations with monochromatic light, 322.
Stahl, E., Compass-plants, 159.
Stars, observations of double, 334.
Stereoscope, reversible, *Stevens*, 226,

Stevens, W. L., new form of reversible stereoscope, 226.
notes on physiological optics, 290, 346.
organ-pipe sonometer, 479.
Stevenson, J. J., coal-field near Canon City, Colorado, 152.
Stone, G. H., glacial erosion in Maine, 242.
Sulphur oxychloride, new, 484.
Sun, parallax of, 161.
heat of, 487.
Swiss Seismological Commission, 337.

T

Telescope tube, flexure of, *Schœberle*, 374.
Temperature, change of from mechanical strains, 321.
diurnal variation of, *Gould*, 99.
Thompson, S. P., Lessons in Electricity and Magnetism, 241.
Tides in early geological time, 323.
Timber line, *Gannett*, 275.
Tones, harmonic and partial, 147.
Trowbridge, J., physical notices, 49, 147, 239, 320, 413, 486.
Tschermak, G., Lehrbuch der Mineralogie, 68.
Tuckerman, E., North American Lichens, 326.
Turner, W., Names of Herbes, 326.

V

Vacuum, electrical resistance of, 149, 487.
Vapor-density of the halogens, 143.
Veitch, J., Manual of the Coniferæ, 69.
Verrill, A. E., Architeuthis at Newfoundland, 71.
Owen's Cephalopoda, 72.
Agassiz's Echinoidea of the Challenger Expedition, 75.
marine fauna of outer banks off New England coast, 135, 216, 309, 406.
Duncan and Sladen's Echinodermata of the Arctic Sea, 247.
Vibrations, effect of on a suspended disc, 51.
Vilmorin-Andrieux, Les Meilleurs Blés, 494.
Viscosity of rarefied gases, 239.
Vision, phenomena of, *Stevens*, 290, 346.
Volcanoes, Judd on, 65.
Vries, H. De, Resinous Matters in Plants, 494.

W

Walcott, C. D., Pœcilopod in the Utica slate, 151.
new genus of Eurypterida, 213.
Waldo, L., Micrometrical Measurements of Double Stars, 334.
Ward, L. F., Guide to the Flora of Washington, 492.
Wead, C. K., millimeter screw, 176.
Wetherby, A. G., distribution and variation of fresh-water mollusks of N. America, 76, 203.
White, C. A., descent of certain fresh-water mollusks, 382.
Whitfield, R. P., paleontological papers, 153, 496.
Whitney, J. D., Climatic Changes of later Geological Times, 489.
Wiik, F. J., Mineral Karakteristik, 69.
Wilder, B. G., Brain of the Cat, 160.
Wilson, S. D., respiration of plants, 423.
Winchell, N. H., Minnesota Geological Report, 62.
clays making cream-colored bricks, 64.
Wires, change of temperature from mechanical strains in, 321.
Woeikof, A., mean annual rain-fall, 341.
Glacial-era climate, 417.

Y

Young, A. A., sandstones having the grains in part quartz crystals, 257.

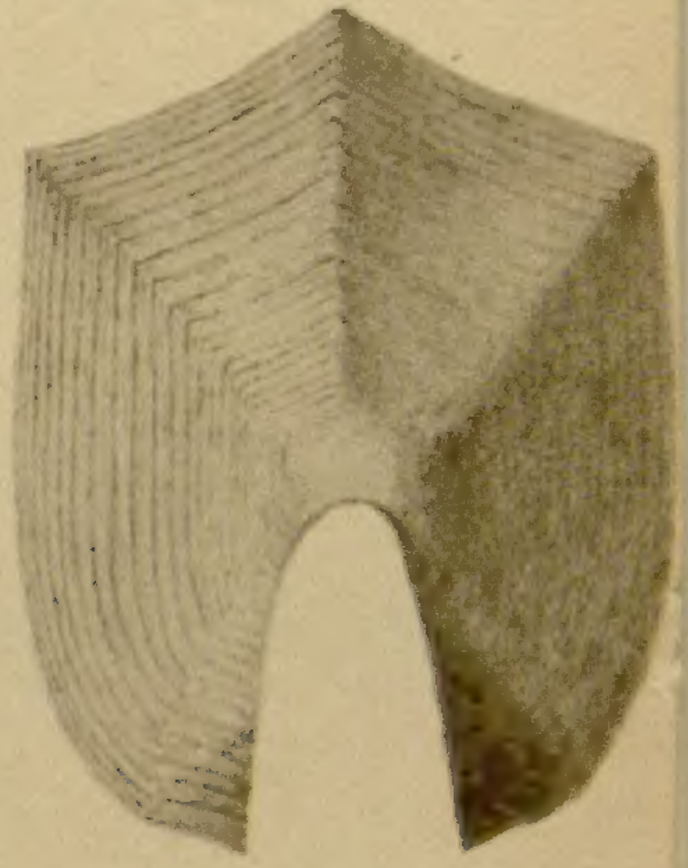
Z

ZOOLOGY—
Actinaria, New England, *Verrill*, 314.
Animals containing Algæ, 328, 329.
Anthozoa, New England, *Verrill*, 309.
Architeuthis at Newfoundland, 71.
Cephalopoda, 72.
Cercaria with caudal setæ, *Fewkes*, 134.
Ducks, domestication of wild, 421.
Echinoderms, arctic, 247.
New England, *Verrill*, 138, 216.
Cretaceous and recent, *Agassiz*, 40.
Gundlachia in western New York, 248.
Madreporaria, New England, *Verrill*, 313.
Marine fauna, New England, *Verrill*, 135, 216, 309, 406.
Mollusks, descent of, *White*, 382.
distribution of, *Wetherby*, 76, 203.
Nomenclature, 157.
"Yellow cells," see BOTANY.
See further under GEOLOGY.

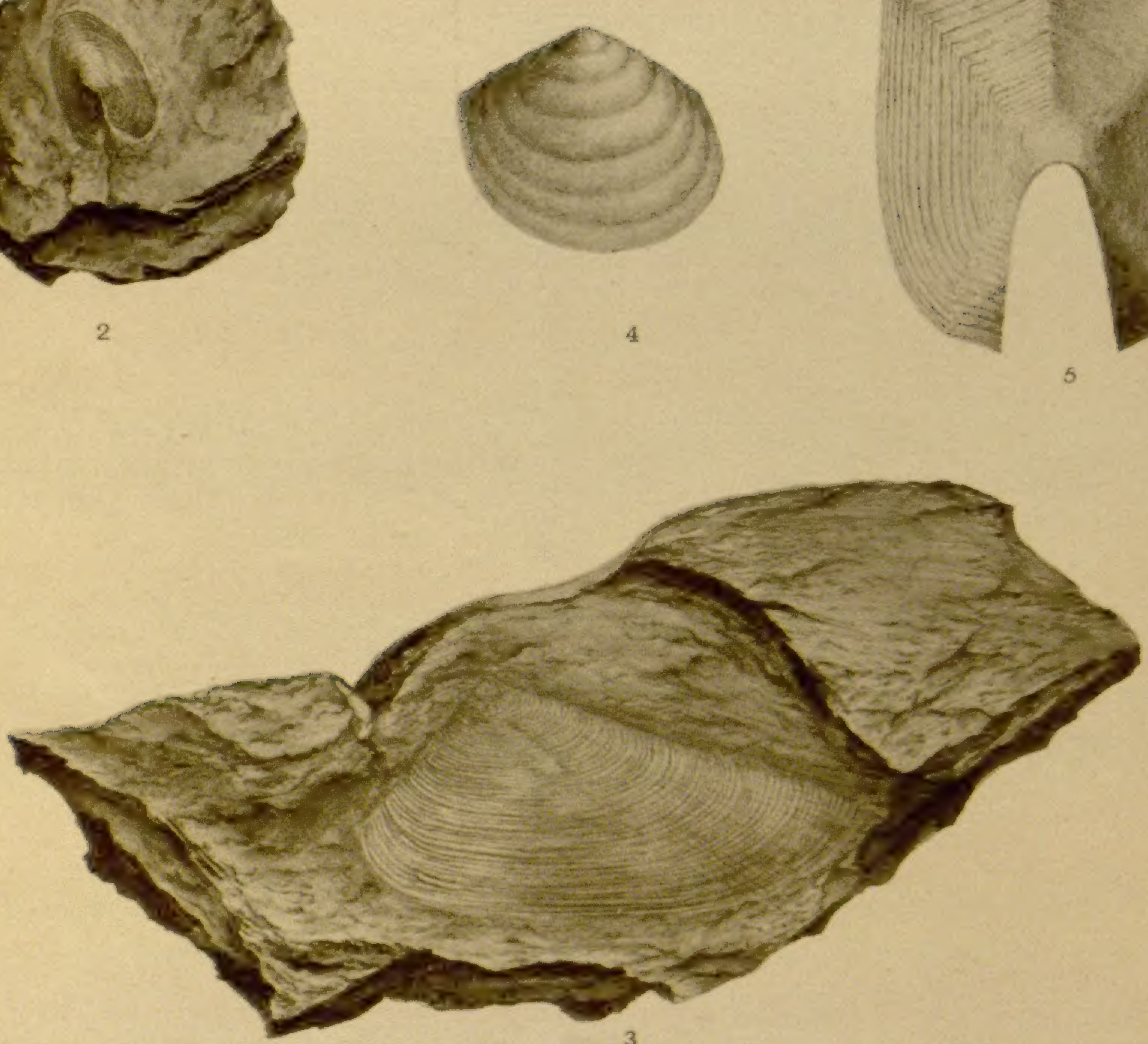
1

2

4



5



3

J. M. C. & R. L. A. DEL.

ARTOTYPE, E. BIERSTADT, N. Y.

1. 2. 3. Spathiocaris Emersonii Clarke
4. Estheria pulex ,,
5. Lisgocaris Lutheri ,,